ZOOLOGY

BEDDARD

ELEMENTARY PRACTICAL ZOOLOGY

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BY

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PREFACE

The present volume is a guide to the elementary zoology required by the Science and Art Department. It embraces all the types comprised in the syllabus issued by that department, with a little additional matter, such as would naturally be given in a course of lectures preparatory for that examination.

As regards the systematic side of zoology, the candidate for the examination is required to know "the characters of the classes of Vertebrates," and to refer "common Vertebrates to their classes." He is also expected to have a similar knowledge of the Arthropoda and of the Mollusca.

Since the types of animals selected for special study comprise several others among the chief groups of the animal kingdom, I have thought in advisable to include a general classification. This is exceedingly brief, but may serve to present the student with a rough notion of the characters of the different groups of animals. I have endeavoured to use in these definitions anatomical characters, which should be familiar to the student after the structure of the types has been mastered.

Inasmuch as the knowledge required from the student who is a candidate for the Science and Art examinations embraces some of the more important generalizations of biology, such as the cellular constitution of animals, the phenomena of reproduction, etc., it is hoped that this book may serve the needs of others who desire an acquaintance with the elements of the subject without a view to any particular examination.

Many distinguished authorities hold that in treating of animal structure it is desirable to commence with the higher forms and gradually work down to the lower forms. It is argued that to do this is advantageous, since the student commences with what must be the more familiar part of the subject. Some rough notion of human anatomy is possessed by most persons; whereas the very methods by which the lower animals are studied are new to the beginner. There is, however, no transition between a dissection of a frog with scalpel and scissors and the examination of an amœba with the microscope. The plunge into an unfamiliar region of the subject must be made some time; and why not at the very commencement? Besides, to begin with the low forms and to gradually work to the higher has the undoubted advantage of presenting the facts in a logical sequence.

I therefore begin with the amœba, and deal with the other types in, so far as is possible, an ascending order.

The types which are described here, as well as the general facts of animal structure, have been dealt with by so many zoologists in so many text-books, that it is hard to illustrate them by fresh drawings. It is quite useless, for example, to attempt to improve upon the excellent figures of the crayfish appendages to be found in Mr. Huxley's "The Crayfish." Such illustrations I have copiously borrowed from various sources which are duly acknowledged in the case of each cut.

Among these will be noticed a few new illustrations, either copied from the original memoirs which they illustrate or modified from existing wood-cuts in text-books; these are Figs. 1–7, 9–13, 22–25, 27–32, 34, 37–41, 43, 45–49, 52, 63, 73, 74, 76. For these I am indebted to the skill of Mr. R. E. Holding.

F. E. BEDDARD.

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ELEMENTARY ZOOLOGY

CHAPTER I.

THE UNICELLULAR ORGANISMS.

THE AMŒBA (*Amœba, various species*).

WATER from any stagnant pool, particularly if a drop be taken from the surface of the mud at the bottom, will be frequently found to contain examples of an organism known as **Amœba.** This term is used rather loosely for a number of creatures—fresh-water, marine, terrestrial (in damp earth)—which agree in being composed of a speck of seemingly jelly-like substance, and in moving by a flowing motion, accompanied by the thrusting out of processes of the irregularly shaped body. Some little experience of these organisms will soon show that there are many kinds of amœbæ, which have been classed by naturalists in different species and even genera;[1] some, for instance, are larger, much larger, than others. The form of the thrust-out processes of the body—the *pseudopodia*, as they are termed—differs from species to species; the more or less granular appearance of the body is another character which varies in the different kinds; and there are other points of difference. In all these organisms, however, the body has no fixed form; it is simply an irregular mass of living matter; hence the name of "Proteus animalcule" was applied to it by some of the earlier observers. When an amœba, preferably one of the larger species, is examined, it is seen to consist of

[1] The terms "genera" and "species" are explained later (see p. 173).

a mass of semi-fluid matter, which in the middle of the body is filled with granules, and is clear, or clearer, peripherally. In

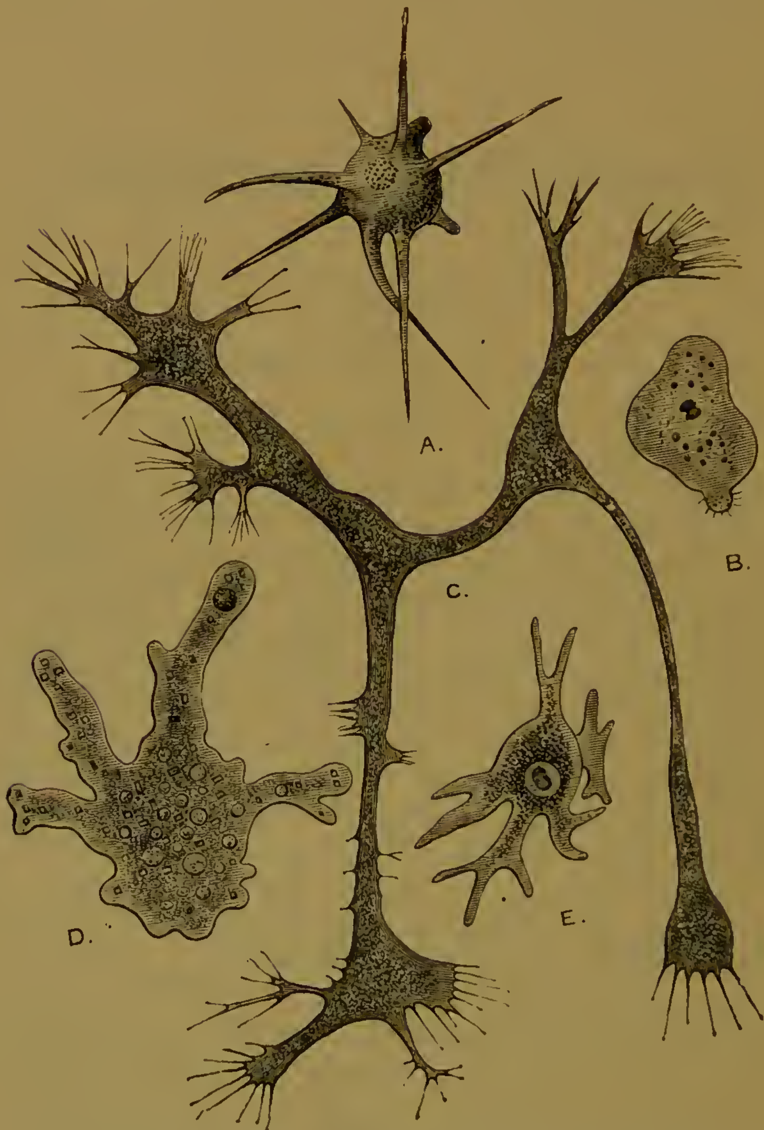

FIG. 1.—Various species of Amœbæ, highly magnified, characterized by the differing forms of their pseudopodia. (After Mœbius.)

the living form sometimes—but it is better shown by staining reagents—a denser central body may be observed of a spherical shape, which has no fixed position, but moves about with the movements of the animal; this is termed the *nucleus.* In many amœbæ a clear vesicle also exists (the *contractile vacuole*), which, if kept under the eye for a few minutes, will be noticed to suddenly contract—apparently expelling its fluid contents—and to gradually fill out again, repeating the process continually.

This is positively the entire anatomy of the amœba, stated, of course, very briefly. No animal simpler in structure than this organism is certainly known. Some amœbæ lack the contractile vacuole; but all consist of a mass of the jelly-like living matter (*protoplasm*) and a nucleus or nuclei. It has been stated that there are amœboid creatures without a nucleus; but this does not appear to be by any means certain. And we shall see later that it is improbable.

The amœba not only has the certain definite structure that has just been briefly described; it also acts; the living matter of which it is built up performs certain functions. We have to consider the physiology (the functions) of the amœba, as well as its structure (its morphology). The movements of the animal have been already referred to. It is continually in motion, and the movements may be retarded by cold, increased by warmth, and again retarded and stopped by too great warmth. Various chemical substances produce similar effects. The living matter, therefore, of which the amœba is composed is capable of movement, and is irritable—that is, responds to stimuli. If an amœba be watched for some time it will be seen to feed. It takes in nourishment by simply flowing over and engulphing a minute plant or other organism; it literally gets outside its food. After a time the ingested food particle will be seen to gradually disappear, and the indigestible residue may be seen to be thrust out of the body. Furthermore, the contractions of the contractile vacuole expel from the body other waste substances. If an amœba be kept in filtered water, in which there is no vegetable or animal matter, it will die after a longer or shorter time. Nor will it avail it that the water be impregnated with the various chemical elements, or compounds of them, that make up its body. The amœba needs organized matter to feed upon.

The body of the amœba, therefore, is constantly wasting away and being as constantly renewed by the taking in of food, which must be in the form of living or dead animal or vegetable matter.

But the animal performs other functions.

When the creature has attained to a certain size, which differs in different species, and even in individuals, it divides into two; the nucleus divides and then the protoplasm, so that where there was one amœba there are two. This process under favourable circumstances is continually repeated. But it has its limits. After a certain number of generations have been thus produced by simple fission—the number varying with the species, and not being accurately fixed—this method of reproduction ceases. Another kind of generation comes into play. Two amœbæ approach and fuse together, the nuclei joining and the protoplasm being commingled. After a longer or shorter period of conjugation the two may become surrounded in a delicate cyst, and break up into a number of minute spores, which gradually attain to the size of the parents after the rupture of the case; or the two may separate, and, refreshed by the union of the nuclei and protoplasm, go on dividing by the process of fission. This conjugation must not be confused with the ingestion of one amœba by another, though in some cases it is doubtless difficult to distinguish between the two—between hunger and love.

The question may be asked, Why should an amœba divide? why should it not go on growing indefinitely? The question is easier to ask than to answer. In considering the matter it must be borne in mind that possibly the viscid and semifluid protoplasm cannot hold together in droplets above a certain size, and (more important) that the surface does not increase in extent *pari passu* with the contained mass; hence the power of ingesting food and excreting waste products may be not sufficiently rapid to keep pace with the growing mass. Accordingly the animal divides into more conveniently sized pieces.

The amœba then moves, responds to stimuli, feeds, excretes, grows, and reproduces itself. These are among the most important characteristics of living matter; and in all living beings the same phenomena are observable, in addition to respiration, which is the taking in of oxygen.[1]

By these characters living may be distinguished from non-living matter. This living matter, "the physical basis of life," or *protoplasm*, as it is usually called, is a viscous semifluid substance with granules interspersed. A certain vagueness of meaning has at times attached itself to the expression protoplasm. It must not be regarded as a substance of definite chemical composition. It is a mixture of various substances, whose exact relations cannot, from the nature of the case, be accurately ascertained. For in order to manipulate it the protoplasm must be killed; and dead protoplasm is an altogether different thing from living protoplasm. In dead protoplasm the actual elements which compose it can, of course, be accurately enumerated; these have been found to be carbon, hydrogen, oxygen, nitrogen, sulphur, and a few others, such as calcium, phosphorus, potassium, sodium, magnesium, and iron. The first five are combined to form various proteids, *i.e.* albumens, globulins, etc. But any account of the chemical nature of the substances would take too long a space, and requires a detailed treatment at the hands of a chemist. Attention, therefore, will be directed only to the bare outline given above, and to the fact that protoplasm is not a chemical but a morphological expression for a complex substance exhibiting the properties already referred to.

Recent microscopical research into the nature of protoplasm has revealed the fact that it has a definite structure, that its particles are disposed in a regular fashion; but the interpretation of the observed facts has differed greatly. The two principal views of the constitution of protoplasm are known respectively as the "network theory" and the "foam theory." According to the first view, the protoplasm is disposed in a network of denser protoplasm, the meshes of which are filled by the more

[1] This function is separated from the others, since the taking in of free oxygen (= respiration) is not quite *absolutely* universal. Thus there are the anaerobiic bacteria, which not only do not take in free oxygen, but are killed by it. They must obtain their oxygen from compounds.

fluid parts; in this case the granules are largely an optical delusion, and represent the nodal points of the meshwork: the granules are also partly "formed" substances, *i.e.* bodies not protoplasm, but produced by the activity of the protoplasm, just as the droplets of fat in a fat cell are formed substances produced by the activity of the protoplasm. A mass of protoplasm, then, on this view, may be roughly compared to a sponge.

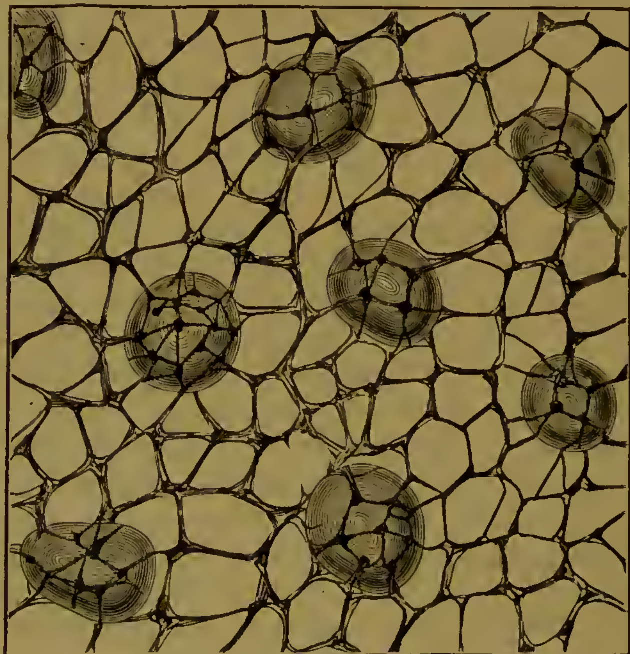

FIG. 2.—A portion of the body of a Multinucleate infusorian *Opalina*, to show network structure of protoplasm. Very highly magnified. (After Bütschli.)

According to the foam or honeycomb theory the living substance of a cell is comparable to a mass of froth, of which the air in the bubbles is formed by less viscid, the walls of the bubbles by more viscid, protoplasm. It will be apparent that so far this view of the constitution of protoplasm does not differ widely from the network view. The protoplasm of various cells and certain simple organisms appears to demonstrate that this foam theory is the true explanation of the arrangement of protoplasm. It is especially well seen in an amœboid creature, *Pelomyxa*, not far removed from the more common forms of amœbæ, and chiefly differing by the presence of a large number of nuclei. Professor Bütschli, moreover, has succeeded in artificially compounding a substance which has many of the physical properties of protoplasm to all appearance. He made a fine emulsion of oil and a solution of such a substance as common salt. This mixture not only showed the foam-like

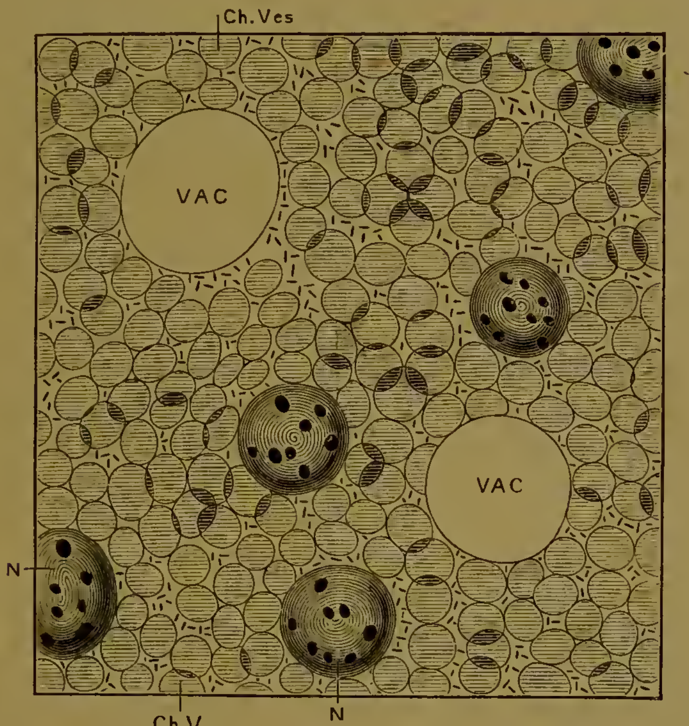

FIG. 3.—A portion of the body of an Amœboid multinucleate organism (*Pelomyxa*), illustrative of foam theory of protoplasm. Very highly magnified. (After A. G. Bourne.)
N, nuclei; VAC, vacuoles; Ch. V., vesicles (tinged green by chlorophyll).

structure, but it exhibited movements; and masses of it even divided in a very life-like fashion. In the case of the "artificial protoplasm" the walls of the bubbles were formed by the oil, and the alkaline solution occupied their interior. This mixture, however, bears a relation to true protoplasm like that of a waxwork figure to a man; it is not a kind of monster of Frankenstein. And, ingenious though the experiments undoubtedly are, they really prove nothing, since protoplasm is admittedly not an oily substance, though it may often contain oil drops formed by its own activity.

Having considered the protoplasm which builds up the bulk of the amœba's body, we may turn to the nucleus. The *nucleus* is a spherical to elliptical structure, encircled by a definite wall, and showing a granular appearance. One or more rounded bodies in its interior are termed *nucleoli*. At one time the nucleus was regarded simply as a denser bit of protoplasm in the interior of the protoplasm, denser perhaps by reason of its central position and the consequent pressure of the surrounding substance. It is now known to be a perfectly distinct structure. This opinion is based upon its minute structure, which has been of late years more elaborately investigated, and by the physiological importance which it has been proved to possess. This is evidently incompatible with a mere central thickening of the protoplasm. The nucleus very commonly exhibits a reticular arrangement of its contents, the denser network consisting largely of a substance which has been termed *chromatin*. But the constitution of the nucleus is more fully entered into below (p. 127) in connection with its multiplication. As to the importance of the nucleus, it seems probable, in the first place, as already stated, that a nucleus is always present in living bodies. There are apparently a few exceptions, such as those minute organisms so often connected with disease, and generally known as bacteria. Figures showing a structure like nuclei in those organisms have been published, but not to the satisfaction of everybody. The view has been advanced that the whole body of the minute plant is a free nucleus with but a slender rim of protoplasm. This may be the case, but the matter cannot be fully gone into here; it is sufficient for the present purpose to insist upon the certainly almost (and probably quite) universal presence of a nucleus. The importance of the nucleus in the protoplasm is shown by the striking part that it takes in the division of the amœba; it initiates this division. Experiments have been made with large amœbæ, and with allied organisms, which tend to show that when the creature is torn up by fine needles into small pieces, it is only those fragments which have a nucleus (in the case of the multinucleate forms such as *Pelomyxa*, already referred to), or a fragment of the nucleus where there is but one, that can reproduce the amœba of which they are a fragment. Bits of detached protoplasm, minus all trace of the nucleus, lead for a time what has been described as a "pseudo-existence," but ultimately decay; during this brief existence, they may perform movements, but these have an abnormal character without the dominating nucleus to direct them. Again, the nucleus of many tissues in the higher animals has been observed to preside over such functions as the formation of yolk in ova, the budding of plant cells; and, in short, it is clear that the functions of the protoplasm are largely directed by the nucleus.

Before leaving the amœba, there is one important event in its life that must be referred to. At times, when circumstances are unfavourable—if, for example, the medium in which the animal is living becomes too dry—the amœba will surround itself with a delicate skin excreted by the protoplasm. In this encysted condition it can survive a degree of dryness which would be fatal to it in its naked and unprotected condition.

The Bell Animalcule (*Vorticella*).

The organism known as the **Bell Animalcule** belongs to the same great division as that which contains the amœba, but to a different group; to this group the name "Infusoria" has been given, originally from the fact that various members of it were to be found in organic infusions. The *Vorticella* is a social, but not a colonial, form common in fresh water; numbers are found living closely together. The creature, as is shown in the accompanying figure (Fig. 4), has somewhat the appearance of a wine-glass supported on a long stalk. When the animal is undisturbed, this stalk is elongated to its full; if the slide upon which a number of the organisms have been placed for examination be jarred, they will contract, and the long stalk is then seen to be thrown into a spiral. At the same time a circle of rapidly moving filaments, which deck the free end of the infusorian, are retracted also.

The vorticella is, like the amœba, an unicellular animal.[1] So far it does not present us with an advance of structure upon the last described organism, which is one of the simplest of organized creatures. But the vorticella is a useful example of a single cell, which is highly specialized in many and different directions; it is still a unit of structure, but illustrates the very great amount of differentiation which can occur in a cell.

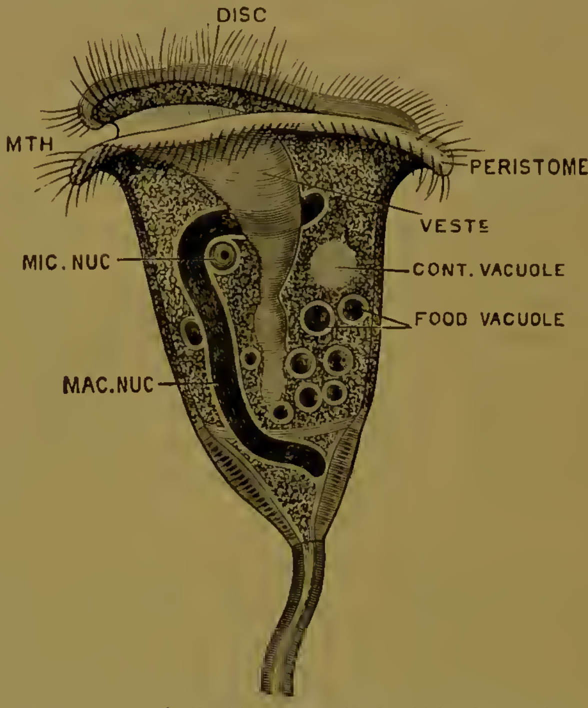

FIG. 4.—Vorticella, highly magnified. (After Bütschli). MTH, mouth; VEST[E], funnel-shaped vestibule; MAC. NUC, macronucleus; MIC. NUC, micronucleus.'

The body of the vorticella is somewhat wineglass shaped; it has a thick rim above, which is, when the animal is fully extended, slightly everted. This rim is fringed with vibratile cilia. Just inside this rim, on one side of the body, is a funnel-shaped depression leading some way into the interior of the animal; this is the aperture through which food particles are taken in. The body itself has a delicate, slightly hardened, outer layer, the cuticula; beneath this is a firm layer, the

[1] This anticipates what is dealt with on p. 14.

ectosarc, and the rest of the body within this, again, is made up of a more granular and softer protoplasm, the endosarc. The stalk is seen to contain a central core in the shape of a delicately striated filament; at its attachment to the body, the filament spreads out fan-wise, and forms a layer of excessively fine fibres lying in the ectosarc. This is termed the *myophan layer*, and is of a muscular nature. It is the muscle in the stalk which enables the contraction already spoken of to be effected. The figure (Fig. 4) shows the layer plainly. The vorticella possesses a contractile vacuole; this undergoes

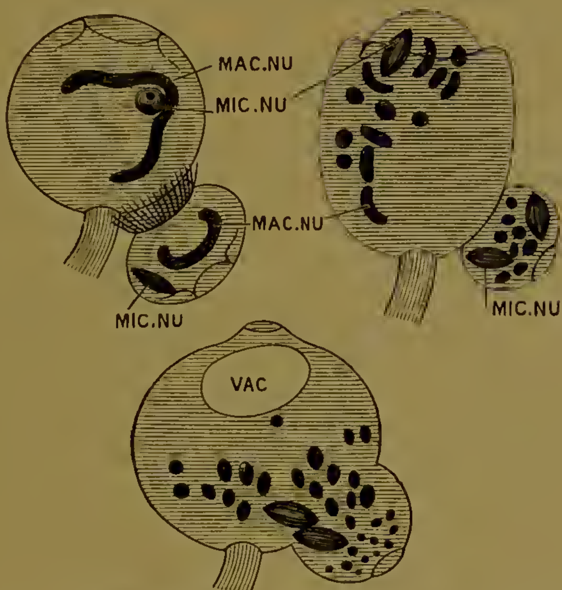

FIG. 5.—Conjugating Vorticellæ, highly magnified. (After Maupas.) MAC. NU, macronucleus; MIC. NU, micronuclei.

regular expansions and contractions. A *nucleus* is present, which has a horseshoe form, and near it a smaller body, the *micronucleus*. The large nucleus is termed the *macronucleus*.

Like the amœba, then, the vorticella is a mass of protoplasm with a nucleus; like the amœba also, the protoplasm is distinguishable into an outer and inner layer, and there is a contractile vacuole; but in other respects the vorticella is more advanced in structure: the ectoplasm is again subdivided into a outer cuticular and an inner layer, below which again is the myophan layer, concentrated in the stalk to form the muscle fibre; while instead of pseudopodia, appearing when and where they are wanted, are definite and persistent outgrowths of the ectosarc, which have the power of independent movement. Yet there is not so wide a difference as might be thought between the heavy, slowly flowing, pseudopodia and the actively vibratile cilia. Some amœbæ have very slender pseudopodia, while organisms belong to the protozoa have long thin fixed processes, from which to cilia is not a long step. Approaching the matter from the other side, cilia have been observed in the living animal to "melt down" into pseudopodia.

The vorticella multiplies by division, and also after what may be termed a sexual union. A bell divides down the middle, and two vorticellæ are the result. This division results in the production of two kinds of individuals; one is like the parent form, the other is a locomotive body with a ring of cilia at each end of the body. The locomotive body, after a longer or shorter interval, settles down and becomes a stalked *vorticella.*[1] Or one of these locomotive individuals will attach itself to a stalked bell, and become fused with it, the nuclei becoming broken up, fusing with those of the other individual, ultimately reacquiring their original form. Ordinary division occurs after this which may be compared to a sexual process. It has been shown that, after a certain number of generations produced by simple division there is a need for this sexual union to restore the exhausted protoplasm.

[1] Sometimes, particularly if the water be too foul, a vorticella will detach itself from its stalk and lead a free existence, forming later a new stalk, and settling down to a sedentary life.

CHAPTER II.

THE HYDRA (HYDRA VIRIDIS, HYDRA GRISEA, ETC.).

THE **Hydra** is a small organism, not more than half an inch in length when fully extended—and that would be a large specimen—which is common in ponds and other pieces of still fresh water. The animal exists in, at any rate, two forms in this country; one set of individuals are green, the others brown or nearly colourless. Hydra has the general shape shown in the accompanying figure (Fig. 6); it consists of a tubular body surmounted by a wreath of tentacles which grow out from the base of a conical expansion; this bears the mouth at its summit. The whole body is retractile, the retracted hydra having an oval to round form. The hydra belongs to a large group of animals containing the jelly-fish of our seas, the "Portuguese man-o'-war," and a variety of soft-bodied creatures which, as will be stated later, form one of the primary divisions of the animal kingdom. This creature leads a stationary life, adhering to a leaf of duck-weed or a fragment of stone or stick, and by waving its arms freely in the surrounding water, catches and narcotizes by means of the thread cells—to be described presently—minute worms, crustaceans, etc., which form its food. The green hydra is coloured green by *chlorophyll*, a pigment which is nearly universal in the vegetable kingdom, being only absent in the fungi and in a few parasitic plants belonging to higher groups.

This chlorophyll is also present in a few other animals, even higher in the scale than hydra, such as the two Planarian worms, *Vortex viridis* and *Convuluta schulzei*. It also exists in a few Infusorians. It is not, however, safe to jump to the conclusion that when an animal is coloured green it is by this particular pigment. Green birds and green lizards, for example, do not in any case owe their colour to chlorophyll.

In order to prove conclusively that a given green pigment is or is not chlorophyll, it should be submitted to three tests—chemical, physiological, and morphological.

Chlorophyll is, as a rule, associated with certain structures, the chlorophyll corpuscles, which are nucleus, like masses of protoplasm tinged with the chlorophyll. This is not the invariable case; but it is safe to regard a green pigment contained in special corpuscles as being chlorophyll, though the converse cannot be asserted. This may be termed a morphological test.

Chlorophyll has certain definite chemical reactions and characters. In the first place it shows a definite absorption spectrum with characteristic dark bands. It is soluble in alcohol, and the solution is fluorescent. By transmitted light it is green, by reflected light reddish. There are, of course, a variety of other chemical methods of deciding whether the pigment is chlorophyll.

Finally, there is the physiological method. Protoplasm can, in the presence of chlorophyll, split up the carbonic acid of the air into oxygen and carbon, combining the carbon with the water in the protoplasm to form —usually starch, but sometimes some other substance, *e.g.* oil, composed of the elements carbon, oxygen, and hydrogen.

Tried by the first two of these tests, the green colour of hydra is chlorophyll.

Experiments, however, appear to show that it is of no great physiological use to its possessor.

Opinions differ as to whether the chlorophyll is really a product of the cells of the hydra (in which case there is a most interesting point of likeness between animal and vegetable protoplasm), or whether the so-called chlorophyll corpuscles of hydra are not to be looked upon as small unicellular plants. If so, this illustrates what is termed *symbiosis;* as the small plants derive advantage (shelter, etc.) from their association with the host, while (though, as already said, this is not so clear) they confer advantages in the shape of starchy or other matters formed by them upon their host.

When a transverse or longitudinal section is made through the hydra, the body is seen to consist of two layers of cells surrounding a central cavity, which latter communicates with the exterior through the mouth aperture before referred to. When a hydra is teased up in water with fine needles, these cells are dissociated from each other, and float freely about. Each may then be seen to consist of a piece of protoplasm, with a more or less centrally placed nucleus. The boundaries of the cells may also be recognized in the sections. The whole body of the hydra is thus built up of a number of structural units or cells, each one of which is the equivalent of a single amœba or vorticella. The hydra, and all the animals lying above it in the series, is "multicellular;" the amœba and the vorticella are both "unicellular." The two layers of cells are known respectively as the *ectoderm* and the *endoderm*, the names referring to their relative positions. The *enteron*, or central cavity, is also

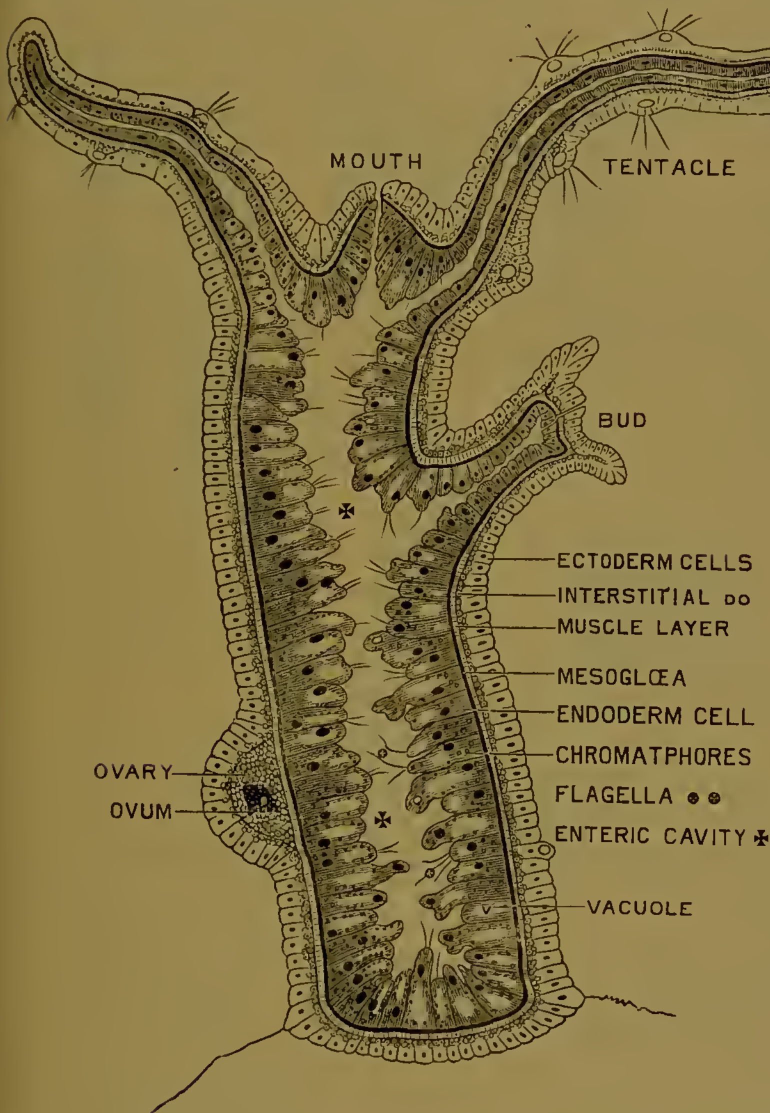

FIG. 6.—Longitudinal section through Hydra. (After Marshall and Howes.) The asterisks (✠) are placed in enteron.

continued into the tentacles. The ectoderm is made up of two kinds of cells; there are, in the first place, large cells somewhat narrowed towards the base, where they end in long contractile tails which are in effeet musele fibres (Fig. 7). Between these larger eells are heaps of small *interstitial cells*, some of which are ganglionic in nature and communicate with fine nerve fibrils. When a living hydra is examined intact, fine bunches of bristle-like proeesses are seen to protrude on the outside; these are the indications of the thread eells, or, better, *cnidoblasts*, as they are not eells, which are partieularly abundant upon the tentaeles. The cnidoblasts (Fig. 8) are formed by the metamorphosis of the interstitial eells, but when fully formed foree their way to the exterior. The fully developed but not used enidoblast has the charaeters shown in the diagram. It is enclosed in an interstitial cell whieh has a delieate proeess protruding on to the exterior; this is the *cnidocil* or palpocil. The funetion of this trigger-like projeetion is not, as might be inferred from the vernaeular name just used, whieh is sometimes applied to it, the grossly meehanieal one; it is probably of a nervous nature, like the fine end of a visual or auditory eell, and eommunieates an impression to the eell, which then contraets and expels the "thread" from the cnidoblast. The latter is a tough sae formed of a spherical or pear-shaped base, with a fine hollow proeess; it has been aptly eompared to a glove with one finger, the hand of the glove being, of eourse, nowhere open.

The "finger," however, is turned inside out within the "hand," and the whole is filled with fluid. Pressure forees out the thread, whieh is then seen to be often armed with spines at its base. The "sting" of the jelly-fish is due to similar thread eells; but whether there is an actual poisonous liquid, whieh eauses the symptoms, or whether it is merely the irritation, like that caused upon sensitive skins by the hairs of certain caterpillars, does not appear to be eertain. From the interstitial eells are also formed the generative tissues, whieh are rounded swellings nearer the tentaeles in the case of the *testes*, and nearer the base in the ease of the *ovaries*. The testes eontain tadpole-like spermatozoa, formed by the divisions of the testicular eells, while the ovary only contains one egg at a time, whieh is large and full of yolk, and exhibits before it is quite ripe amœboid movements. The ovum nourishes itself upon the small cells of the ovary, which might otherwise become ova. There is thus, it will be observed, a "struggle for existence" among the very cells of a particular organ. Though the egg eats up other cells like an amœba, the process is not really different from that

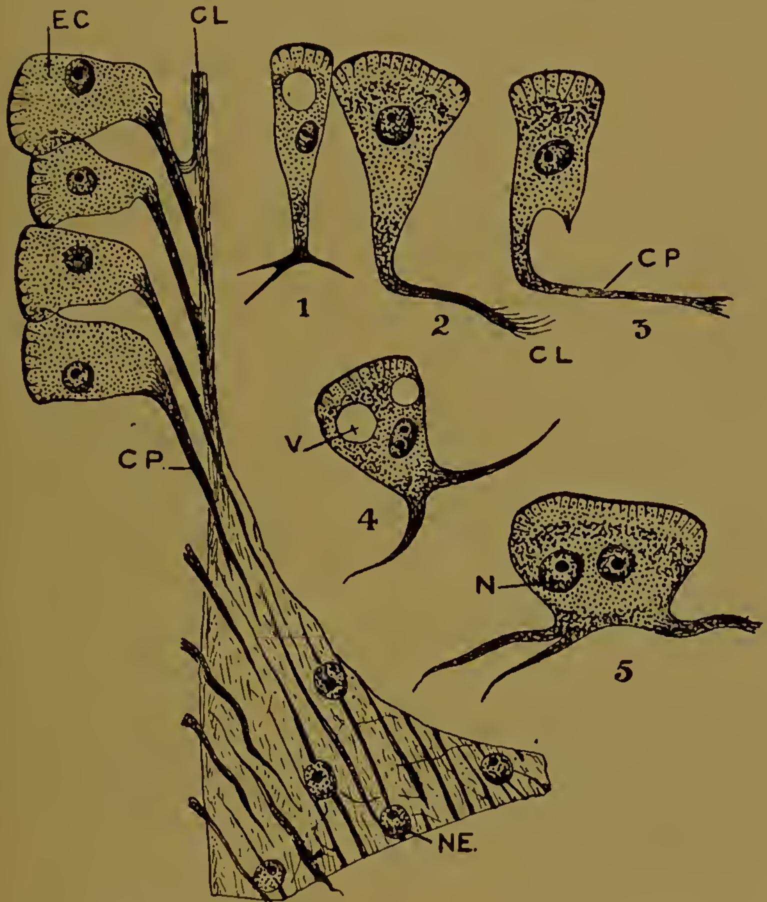

FIG. 7.—Isolated ectodermic cells of Hydra. Highly magnified. (After Howes.) EC, ectoderm cells; CP, muscular process; CL, supporting lamella; NE, nervous cells; 1–5, cells entirely detached from supporting lamella; V, vacuole.

exhibited by other ova, which, as explained elsewhere, are fed by the cells of the follicle.

The endoderm is made up of large cells, many of which have one or more vibratile cilia depending from the inner surface; it is they which bear the chlorophyll corpuscles. Between the two layers is a colourless, thin, structureless membrane, the *supporting lamella*, which is simply an excretion of the cells which border it, as is the cuticle of the earthworm an excretion of the epidermis.

It will be noticed, therefore, that the hydra's body is built up of two distinct layers of cells which are different in character and in function; the outer layers provide the sensitive muscular and protective elements, the internal the digestive. The distinctness of these two layers may be impressed upon the mind of the student by relating a curious chapter, or rather paragraph, in the history of error, which concerns this animal. An ingenious naturalist of the last century succeeded in inducing hydras to swallow a worm attached to a thread, and then pulling on the thread when the worm was fairly swallowed, turned the creature inside out. He asserted that this reversal made no manner of difference to the animal, who thereupon used its outer coat as a stomach, and its stomach as a covering. But a still more ingenious Japanese naturalist confirmed, it is true, the statement that a hydra could be with ease turned inside out; but found also that when left to itself the hydra quietly reversed matters, and assumed its original condition. The cells, in fact, are specialized to perform their several parts, and could not play any other.

FIG. 8.—Thread cells of Hydra. Highly magnified. The thread is everted in the left-hand figure.

CHAPTER III.

THE EARTHWORM (*LUMBRICUS AND ALLOLOBOPHORA, VARIOUS SPECIES*).

IN dissecting the **Earthworm,** the beginner will often find slight discrepancies between the descriptions in the book which he uses as a guide and the actual facts of structure before him. This is owing to the existence of a considerable number of different species of earthworms which offer a certain amount of structural differences among themselves.

In this country there exist, so far as is known, some twenty species. They are all of small to moderate size, and live in soil, though not impatient of even prolonged immersion in fresh water. They burrow through the earth, swallowing the soil as they go, which is often—after extraction of some, at any rate, of the nutritive substance which it contains—evacuated to form the well-known castings so abundant upon lawns after rain. A certain amount of moisture is necessary for the soft-bodied animals to live, and in very dry weather the worms penetrate deeper into the ground, and often coil themselves into chambers below the surface and surround themselves with a coating of exuded mucus.

An earthworm is a soft-bodied animal, obviously *segmented*, *i.e.* the body is divided by superficial furrows into a series of similar rings, segments, or somites, as they are variously termed. A closer examination shows that there are other external features which are also arranged in the same "metameric" fashion. If a worm be held in the hand and passed between the finger and thumb of the other hand, it produces a sensation of roughness, which is caused by the implantation of the bristles, or *setæ*. These setæ are disposed in a perfectly regular way upon each segment, and have—with a few exceptions to be noted immediately—an identical arrangement in successive segments.

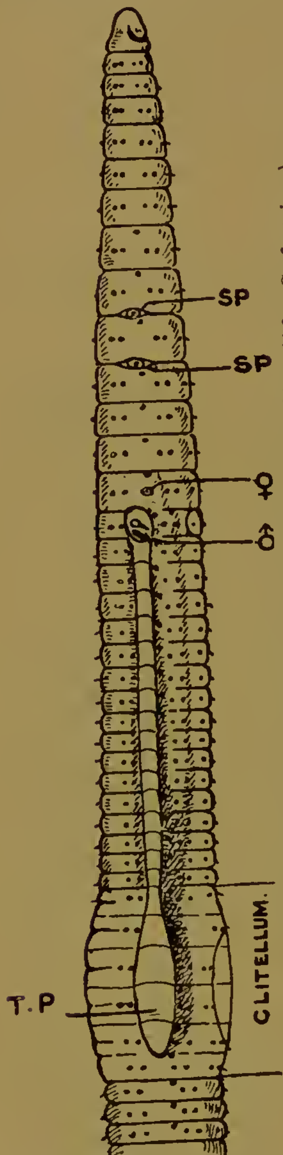

Fig. 9.—External characters of an Earthworm, seen from the side. (After Cerfontaine.) sp, spermathecal pore; just behind these, and in a corresponding situation in successive segments, are the nephridiopores indicated by black dots; the setæ are indicated also by black dots; ♀, points to oviducal pore on segment 14; ♂, spermiducal pore; TP, tubercula pubertatis; a ridge connects the anterior of these with the male pore.

In each segment of the body there are eight of these setæ disposed in couples, the individual setæ of which are more or less closely related; the greater or less distance which separates the two setæ of a couple is frequently a specific distinction. On the first segment of the body the setæ are totally absent, as also upon a projection of the first segment—the *prostomium*, or buccal lobe—which overhangs the mouth. All the other segments have setæ. The worm's body is covered externally by a delicate transparent *cuticle*. If a worm be allowed to macerate for a short time this cuticle becomes easily detachable, and when a portion is stripped off the setæ occasionally come away with it. The setæ, when thus isolated, are seen to be of a yellow colour, and to be regularly curved like an elongated S, or like the mathematical sign ∫, the blunter end being that which is implanted in the body wall; the sharply curved hook in which it ends at the other extremity protruding freely on to the exterior. Upon the clitellum the setæ are of a different kind; they are longer as well as rather thinner and less curved. The *clitellum*, to which reference has been made, is a region of the body which stands out conspicuously by reason of its glandular, smooth, and swollen appearance. It occupies a variable number of segments, and commences at a variable segment, the variability corresponding with different species. It never, however, commences further forward than the twenty-third or twenty-fourth segment. The clitellum is sometimes termed the cingulum or the girdle. At the commencement of the clitellum there are on the ventral surface of the body certain glandular eminences, more conspicuous in immature worms in which the clitellum is not yet formed. These, again, vary in number and position according to the species, and are known as the *tubercula pubertatis*.

If an earthworm be dried with blotting-paper and then gently squeezed, liquid will be seen to exude or even to spirt out from certain pores placed along the back. These are the *dorsal pores*, and lie in the middle line of the back between successive segments. They do not begin for some distance behind the anterior extremity, and the exact segment at which they do commence is another of those points which varies with the species. A careful examination, especially of spirit-preserved examples, shows a second series of pores, which, unlike the dorsal pores, are paired, a pair to each segment. These lie laterally, and are placed in front of the more ventral couple of setæ. Their position, again, varies somewhat in some species, and they are not apparent on the first two or three segments of the body. These pores are termed the *nephridio-pores;* they are the openings of the excretory organs.

On the fifteenth segment of the body are a pair of very conspicuous orifices with tumid lips, lying between the dorsal and the ventral pair of setæ. These *orifices* are those *of the sperm ducts*, but in some species they are not so obvious as in others. On the segment in front of this—*i.e.* the fourteenth—are two other orifices very minute and not always easy to see, the *oviducal pores*. Less easy, again, to see are a series of pairs of orifices not fewer than two pairs, lying generally between segments 9 and 10 and 10 and 11. These are the

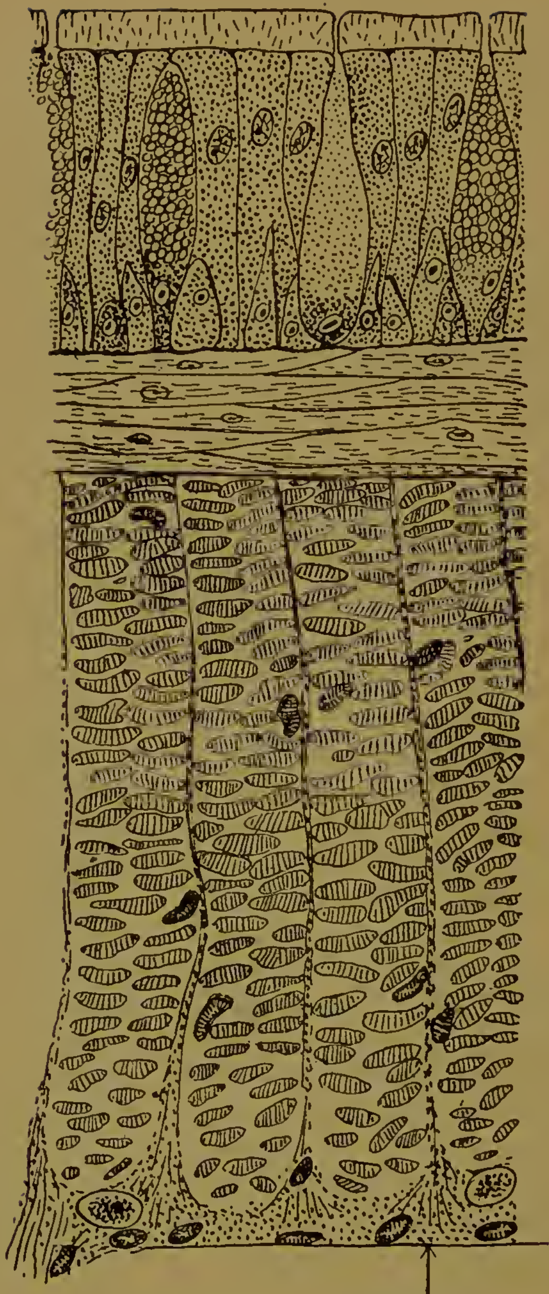

FIG. 10.—Transverse section, body wall of Earthworm. (After Cerfontaine.)

spermathecal pores. Finally, there is the *mouth* in front, already referred to as lying beneath the prostomium, and the *anus* posteriorly, entirely surrounded by the last segment of the body.

Such are the principal external characters of the earthworm. It will be observed that the setæ, the dorsal pores, and the nephridiopores show the same plain segmentation as the divisions of the body to which they accurately correspond.

When an earthworm is opened by a median incision along the back, and the flaps of skin turned back, the entire anatomy is revealed.

The Body-wall.—This flap that has just been turned back is built up of three layers. Outside there is an epidermis, within that two muscular layers, an outer circular and an inner longitudinal, shown in the accompanying figure (Fig. 10).

The *alimentary tract* is seen passing in a perfectly straight line from end to end of the body, and from it a series of delicate transverse septa reach the body-wall, forming a means of suspension of the digestive tube. These *septa* divide the body into a set of chambers, through which the digestive tube passes, but which it does not entirely fill. There is left a considerable space, above, below, and at the sides of the tube. This cavity, or series of cavities, is known as the body cavity, or *cœlom.* The septa, roughly, not always quite accurately, correspond at their insertion on to the body-wall to the furrows which separate the segments externally. The interior of the worm's body is therefore segmented like the exterior, and the internal segmentation corresponds to the external. The chambers of the cœlom, which are divided from each other by the successive septa, are not, however, completely separated. On the ventral side the septa are defective, being cut away along a curved line, so that there is an actual communication between the whole series of cœlomic compartments, and the fluid which is contained therein can pass from end to end of the body. Lying in each compartment of the cœlom is a pair of delicate coiled tubes, the excretory organs, or *nephridia.* The term "segmental organ" was originally applied to these glandular tubes in order to express their segmental

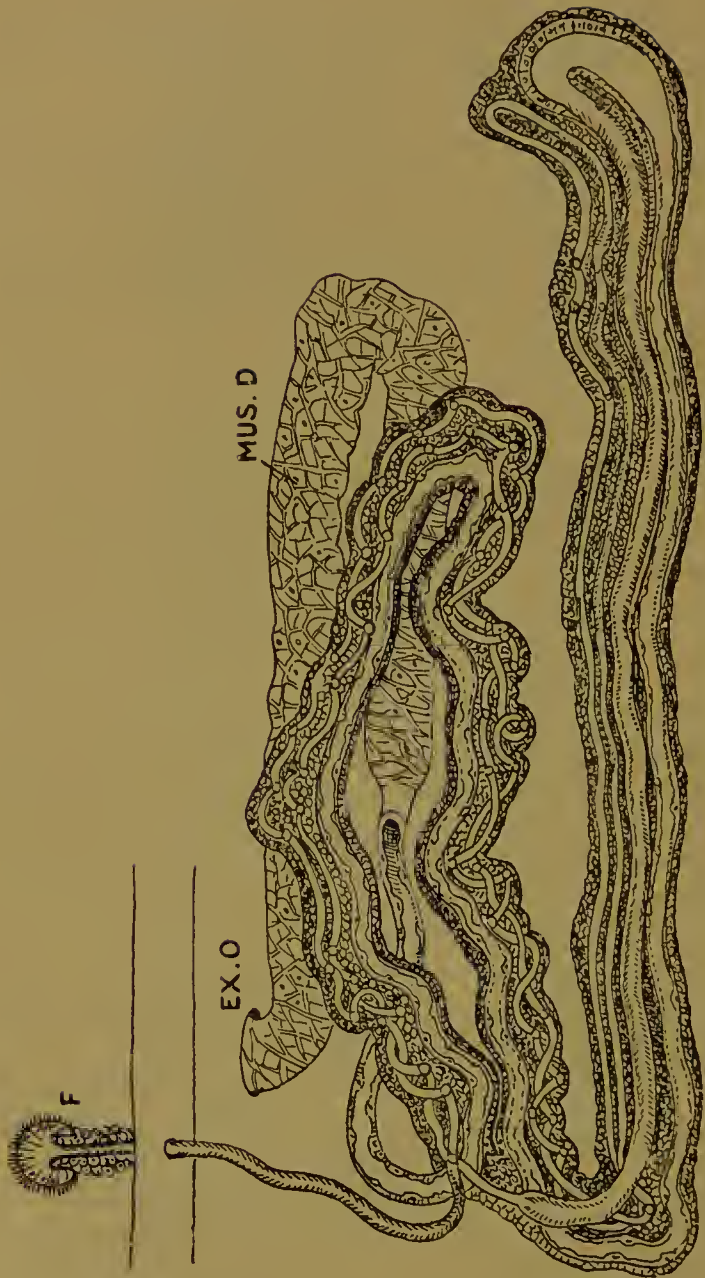

FIG. 11.—A nephridium of Lumbricus. Magnified. (After Benham.)

F, funnel; EX.O, external orifice. The tube is seen to perforate the septum, form a complicated coil, and open into MUS.D, the terminal muscular sac.

arrangement. The nephridia are tubes which, though very long, do not occupy much space owing to the fact that each tube is coiled several times upon itself in the way illustrated in the figure (Fig. 11). The nephridium commences by an open mouth, the *funnel;* this is immediately continued into a delicate tube which passes backwards and passes through the septum into the segment behind. It then winds about in the way illustrated, and ultimately opens into a wider sac, which itself opens on to the exterior by the nephridiopore already mentioned.

The *circulatory system* is complicated and highly developed. The main trunk is a *dorsal vessel* running upon the upper surface of the alimentary tract. This is rhythmically contractile, the contractions passing from behind forwards. This communicates by several large, also contractile, "*hearts*," with the ventral vessel which is not contractile. This lies above the nerve-cord; the blood in it flows from before backwards. Beneath the nerve-cord is another longitudinal vessel, and in the œsophageal region a short vessel on either side of the œsophagus which arises from the dorsal vessel. The dorsal vessel in the segments lying behind this lateral œsophageal vessel gives off a series of regularly and segmentally arranged branches to the alimentary canal and to the septa. Branches also arise from the ventral and subneural vessels supplying the nephridia and body-wall. The vascular system of the earthworm is everywhere a perfectly closed system, consisting of tubes of regular diameter gradually decreasing in calibre as the periphery is reached. The contained *blood* is red in colour, the colour being due to hæmoglobin dissolved in the plasma. In the plasma float a few corpuscles, which seem to be little more than the nuclei of the cells forming the blood-vessels.

The earthworm has *no* special *respiratory organs.* The blood capillaries approach so near the surface of the body—actually into the epidermis in the clitellar region—that the skin itself serves as a respiratory organ.

The *alimentary canal* is a straight tube. The mouth, just below the prostomium, leads into a *buccal cavity*, and that

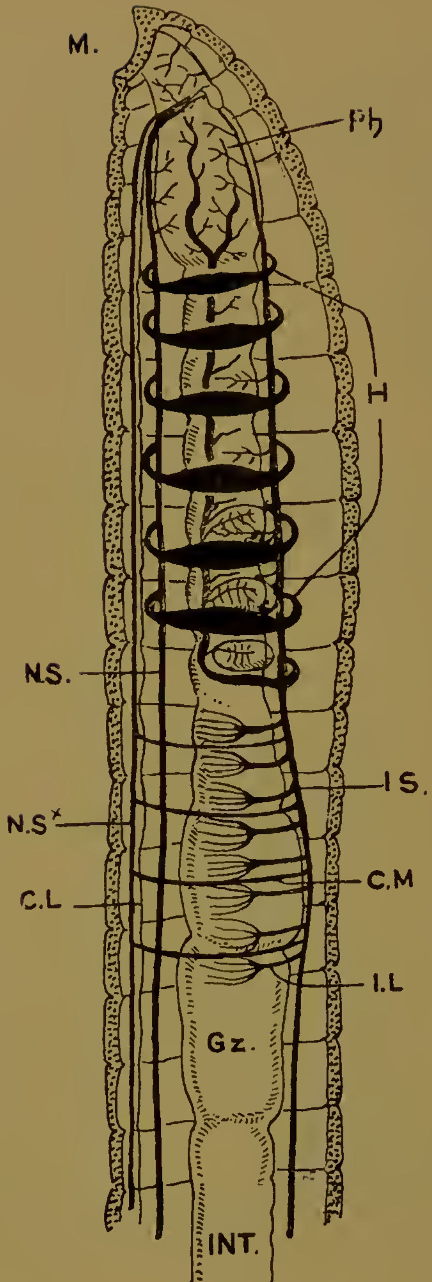

FIG. 12.—Vascular system, and alimentary tract of anterior segments of Earthworm. (A combined figure after Howes.)

H, "hearts;" M, mouth; Ph, pharynx; Gz, gizzard; INT, intestines; IS, dorsal vessel with two sets of branches (C.M and I.L); C.L, nervous system; N.S, supra nervian blood-vessel; N.S*, infra nervian vessel. Anteriorly the lateral vessel is seen springing from the dorsal vessel behind the last heart and the last calciferous gland.

(N.B. The origin of lateral vessel is different in other species.)

again into the *pharynx*. The pharynx has very muscular walls, and from it arises the *œsophagus*, a narrower tube. Attached to the walls of the œsophagus are one to three pairs of *glands*, situated in the tenth to the twelfth segments. The first of these, when there are three, as in Fig. 12, opens into the œsophagus, and is sometimes distinguished from the others as œsophageal pouches. The two other glands open into each other and then into the pouch in front, so that on each side of the body there is a chain of glands opening by means of the most anterior one into the œsophagus. These *œsophageal glands* are sometimes termed the calciferous glands, or "glands of Morren;" their function is to secrete carbonate of lime. The œsophagus dilates in segment 13 into a thin-walled wide *crop*. Immediately upon this follows a thick-walled *gizzard* with a particularly thick chitinous lining. After this comes the *intestine*, which passes to the anus at the opposite extremity of the body. The dorsal wall of the intestine is folded, and the fold projects into the lumen of the gut, thus increasing its secretory surface. This fold is known as the *typhlosole*. The intestine is covered externally with a yellowish mass (the *chloragogen*), which consists of large cells containing excretory products. These cells, sometimes, but erroneously, spoken of as the hepatic cells, are simply that portion of the lining of the cœlom which lies upon the gut.

The earthworm's *nervous system* chiefly lies upon the ventral surface of the body within the body cavity. It is a continuous chain, with a swelling to each segment; the swellings are the ganglia, which contain the bulk of the nerve-cells; the intermediate thinner parts are the connectives which unite ganglion with ganglion. At the anterior end of the body, lying on the dorsal surface of the gut just in the furrow which divides the buccal cavity from the pharynx, is the double supra-œsophageal ganglion. This is connected with the ventral chain by a commissure running round the gut. The *reproductive organs* of the animal are complicated. The essential organs are the *ovaries* and the *testes*, collectively spoken of as the *gonads*. These are simply local proliferations of the lining cellular membrane of the body cavity. The testes are two pairs of little pear-shaped bodies attached on either side of the nerve-cord to the septa, which separate segments 9, 10, 11. The ovaries occupy a precisely similar situation in 13.

Besides these essential organs, which produce respectively spermatozoa and ova, there are ducts which carry off the genital products. Opposite to each testis (but wrapped in certain sacs which will be spoken of immediately) is a much-folded funnel-shaped structure—the *funnel of the vas deferens.* Each vas deferens is continued into a narrow tube; the two tubes of each side soon unite to form a single tube, which opens on to the exterior by the orifice already referred to upon the fifteenth segment. Similarly, opposite to each ovary is a wide and folded funnel—the internal aperture of the *oviduct.* This opens into the very next segment—*i.e.* the fourteenth—on to the exterior. When the earthworm is mature, there are a series of sacs developed by growths of septa, termed the *sperm sacs*, or the vesiculæ seminales. Of these there are 2–4 pairs lying in segments 9, 10, 11, 12; and, in addition, in 10, 11 a single median, or paired, sac, with which these paired sacs communicate. Hence there is a considerable space taken up within the segments mentioned. In these sacs lie the testes and the funnels of the sperm ducts. Thus the sperm which ripens in the sacs cannot fail to find its way to the exterior, when fertilization takes place. A minute body lying on the septum, bounding the thirteenth

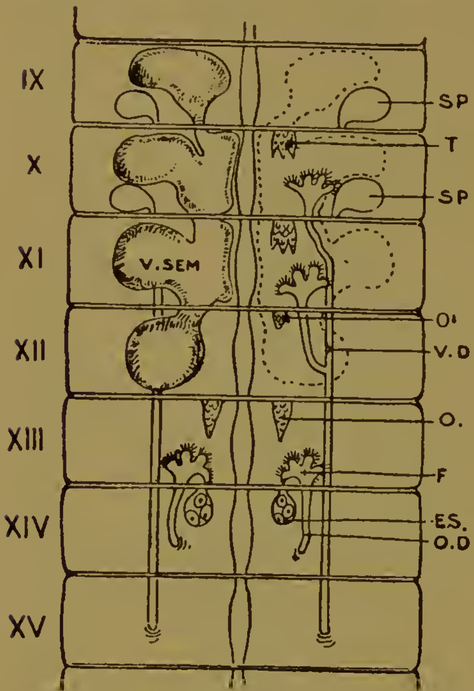

FIG. 13.—Reproductive organs of Lumbricus (*sensu lato*).
The segments are numbered. T, testis; SP, spermatheca; V.SEM, sperm sac; O, ovary; O', rudimentary ovary of segment XII.; V.D, sperm duct; F, funnel of oviduct; O.D, oviduct; E.S, egg sac.

segment behind, usually of a reddish colour, is a corresponding sac belonging to the female system; it is known as the *receptaculum ovorum*, or, better and more simply, as the *egg sac*, or ovisac. It seems, however, that, though this structure corresponds to the sperm sacs, it has no important function. Finally, there are two (or three or more) pairs of *spermathecæ*, oval to spherical blind pouches opening on to the exterior by pores lying between segments 9, 10 and 10, 11.

The earthworm lays its eggs in cocoons, which are chitinous structures fabricated by the clitellum. When formed they are drawn over the head, the worm gradually withdrawing itself. As they pass the generative orifices they receive ova and sperm (the latter being derived from another individual, who deposits it in the form of little cases sticking to the skin, the so-called spermatophores), as well as albumen for the nourishment of the growing embryos; this latter is derived from glands—the *capsulogenous* or albumen glands—which are developed during sexual maturity in the neighbourhood of the sexual organs.

CHAPTER IV.

THE CRAYFISH (ASTACUS FLUVIATILIS).

THE **Crayfish** is common in many streams of this country, as well as on the Continent.

A very slight examination of a specimen will show that it is an animal made up, like the earthworm, of a series of segments. But it will soon be noticed that this segmentation is clearest in the posterior (abdominal) region of the body, and is less obvious anteriorly. Furthermore, the number of segments into which the body is divisible is much less than in any earthworm, and the number is absolutely constant. Each segment, too, is provided with a pair of jointed limbs, or appendages. It is from this character that the name of the great group to which the crayfish belongs (Arthropoda) is derived.

The body is covered with a *hard shell* externally, which corresponds to the *cuticle* of the worm or to the shell of the anodon. Like the latter, it is indurated by the abundant deposition of calcareous salts. Were the whole exoskeleton to be thus permeated with carbonate of lime, locomotion would be clearly impossible; so we find that the skeleton is ringed, denser tracts alternating with softer tracts; upon the latter the former move. When the abdomen, for instance, is straightened, the softer tracts of the exoskeleton are seen to disappear beneath the calcified plates. In the anterior region of the body, however—the *cephalothorax*—the entire back and sides of the animal are covered by a continuous hard plate. This represents a number of the separate hard plates of the abdominal region fused together. The term *carapace* is applied to this anterior plate; it may be distinguished by an oblique (cervical) groove into two parts—an anterior cephalic and a posterior thoracic region.

If one of the abdominal segments be examined, it will be seen to consist of a ring of calcified cuticle oval in section. The dorsal part of this is the *tergum*, the ventral part the *sternum;* there is a ventro-lateral flap projecting downwards, and partly concealing the limbs known as the *pleuron.* Finally, there is at the junction of the pleuron and the sternum a tract of limited dimensions, termed the *epimeron.*

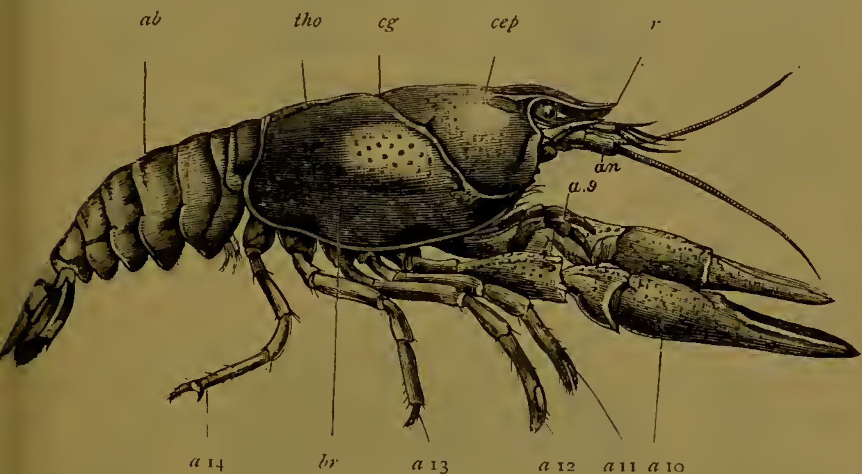

FIG. 14.—The Crayfish (*Astacus fluviatilis*).

r, rostrum; *cep*, cephalic shield; *tho*, thorax; *cg*, cervical groove, between head and thorax; *ab*, abdomen; *br*, branchiostegite; *an*, antennæ; *a* 9–14, thoracic appendages.

This last lies just above the joints for the articulation of the limb on each side.

In the cephalo-thoracic region precisely the same parts can be distinguished, but their several proportions are different. A section through the thorax is shown in Fig. 25, p. 48. The tergum and the sternum are more limited; while the pleura are great laterally descending plates, forming a covering for the subjacent gills, and are hence termed the *branchiostegites;* finally, the epimera are long plates of thinnish and imperfectly calcified membrane. In addition, this region of the body possesses what is called the *endosternal skeleton;* this is formed of ingrowths of both the sterna and the epimera; the nervous system is sheltered by the framework thus formed.

It has been said that the cephalo-thorax represents a number of fused segments of the body. This is proved by three principal facts; in the first place, the general structure is the same, divisible into terga, sterna, epimera, etc.; secondly,

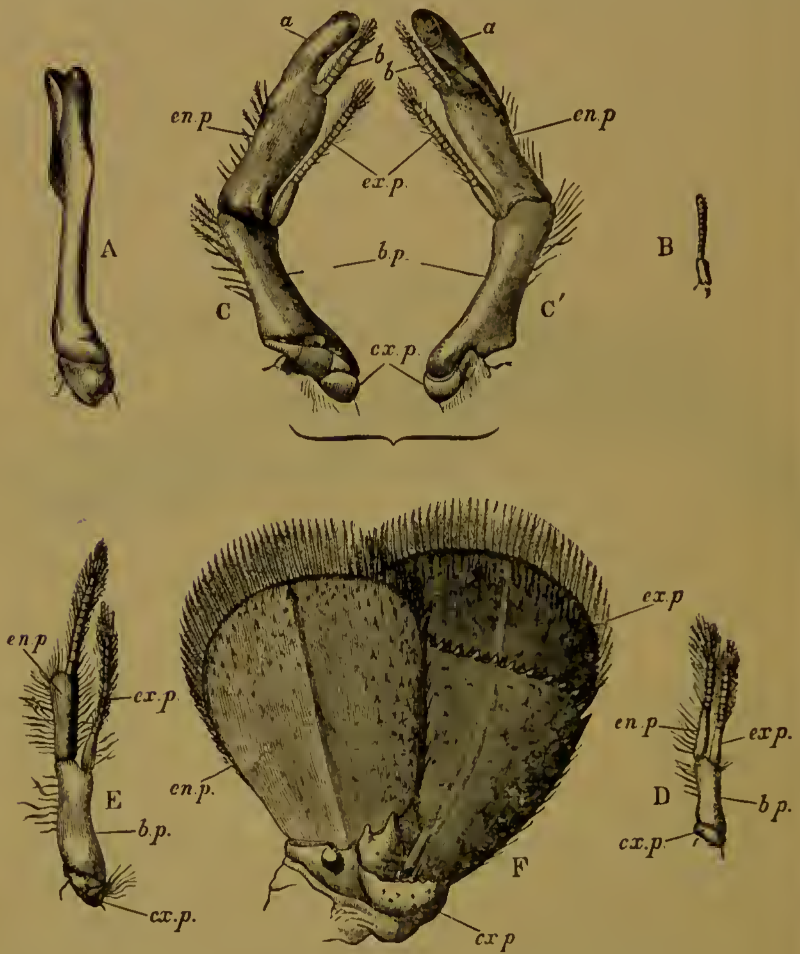

FIG. 15.—Abdominal appendages of Crayfish. (After Huxley.)

A, first appendage of male; B, do. of female; C, second pair of male; D, E, succeeding swimmerets; F, tail swimmerets; *en.p*, endopodite; *ex.p*, exopodite; *b.p*, basipodite; *cx.p*, coxopodite; *a*, *b*, divisions of endopodite.

the sterna are separate, and finally, to each sternum corresponds a pair of appendages.

The posterior end of the body is formed by a two-jointed plate, the *telson*, which is not usually regarded as having the value of a segment. In the same way the body ends anteriorly in the projecting rostrum. The crayfish, enclosed as it is in this rigid "skin," could not grow were it not for the fact that the shell is shed at intervals, a new cuticle having been in the mean time formed beneath the old one.

Each segment of the crayfish's body is provided with a pair of appendages, which are not invariably locomotive, but perform, as will be seen, various functions. It will be convenient to commence with one of the abdominal swimmerets which shows the limb, it is believed, in its simplest form.

The third abdominal appendage is shown in Fig. 15, E. It consists of a basal portion, with two branches arising from this; the basal part is termed the *protopodite*, its two distal branches, according to their position with reference to the body, the *exopodite* and *endopodite*. The limb is thus a biramous structure, shaped like a Y. The protopodite really consists of two separate calcareous pieces separated by a soft tract; it is, in fact, two-jointed. To these two joints the names *coxopodite* and *basipodite* are applied. The endopodite consists of a large terminal joint and a shorter annulated joint; the exopodite, which is smaller, has the same divisions, but the annulated part is proportionately longer. This description applies, not only to the limb from which it has been drawn, but also to the fourth and fifth of the abdominal limbs. The first two abdominal appendages not only differ from this, but differ from each other according to the sex of the individual. In the female the second pair are the same as the limb which has just been described, but the first pair are very rudimentary structures; they have merely a short protopodite and a feeble flagellum, the whole limb varying much in length, as is common with rudimentary organs. In the male, the first pair of abdominal limbs is a stiff scroll-like structure, shown in the figure (Fig. 15, A). The boundaries between protopodite, exopodite, and endopodite cannot be distinguished. In this sex the second pair of limbs is particularly strong; the basal piece of the endopodite is much larger, and ensheathes (Fig. 15, C *a*, *b*) the small flagellum. We have, finally, to consider the tail swimmerets, or *uropoda*, as they are often termed. These are powerful swimming organs, at first sight very different from the comparatively feeble limbs that we have been studying; but they are plainly reducible to the same elements. There is the protopodite, of two joints; then both exopodite and endopodite, of which the former only is plainly two-jointed. The joints, moreover, are strong and flattened plates, not annulated flagella-like outgrowths (Fig. 15, F).

Working forwards from the first pair of the abdominal appendages, the next five pairs (Fig. 16) are ambulatory appendages: they are used for walking; and the fact that there are five has given the special group of arthropods to which the crayfish belongs the name of Decapoda. As their function is different from that of the swimming swimmerets, so their structure is also different. If we take one of the last of these limbs, it is seen to be made up of seven joints of varying lengths, which are thus named, commencing with that which articulates with the body: *coxopodite*, *basipodite*, *ischiopodite*, *meropodite*, *carpopodite*, *propodite*, *dactylopodite*. These joints are to be found in all the five pairs of ambulatory limbs; but in the three first of these appendages the propodite is lengthened out into a process which lies parallel with the dactylopodite, and forms with it a pair of "pincers." In the first pair of ambulatory limbs these are especially well developed, and the whole appendage is larger, being called the *chela*. It is not, at first sight, obvious how these ambulatory limbs can be brought into line with the abdominal swimmerets. They are uniramous, and not biramous. If it be supposed that they are uniramous through the loss of one branch, which branch has been lost, the exopodite or the endopodite? The crayfish itself supplies no answer to this question; but its near ally, the lobster, does, a fact which shows the necessity of a *comparative* study for the unravelling of such problems.

When the young lobster is newly hatched, its thoracic appendages are in the "schizopodous" condition, as it is termed, *i.e.* each is biramous; later on the outer branch disappears, and that which is left is thus the endopodite. It may be inferred, then, on account of the detailed likeness between the thoracic appendages of the lobster and the crayfish, that the thoracic limbs of the latter consist of protopodite and endopodite. We next come to a set of limbs which subserve the function of manducation: they assist in comminuting

FIG. 16.—Thoracic limb of Crayfish. (After Huxley.)
br, podobranch; *cxp*, coxopodite; *bp*, basipodite; *ip*, ischiopodite; *mp*, meropodite; *cp*, carpopodite; *pp*, propodite; *dp*, dactylopodite; *cx.s*, coxopodite setæ; *e*, epipodite.

the food. Here again we should expect to find what we do find, that a difference of function is accompanied by a difference of structure. These limbs are termed—those next to the ambulatory limbs—the *maxillipedes*, consisting of three pairs; then follow two pairs of *maxillæ*, and finally a single pair of *mandibles*. The maxillipedes, as their name denotes, are not exclusively manducatory appendages; they are partly ambulatory, and are intermediate in structure. They are, however, more "typical" in their formation than the ambulatory appendages. They are all biramous. The last pair (see

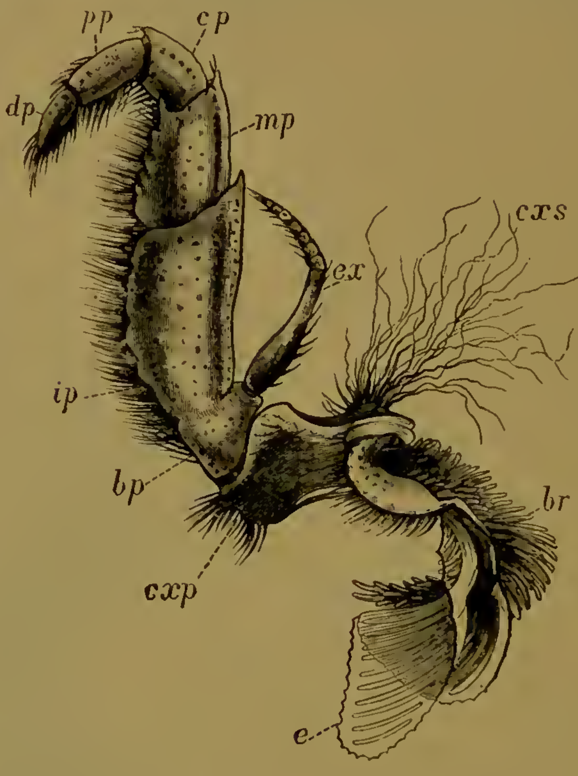

FIG. 17.—Third maxillipede of Crayfish. (After Huxley.)
c.x, exopodite; other letters as in Fig. 16.

Fig. 17) has a protopodite and an endopodite much like that of the ambulatory limb; the details of difference can be gathered from an inspection of the figure. But it has, in addition, an exopodite, shorter than the endopodite, and ending in a flagellum like that of the swimmerets. The pair of appendages in front of this, the second maxillipedes

(Fig. 18, B), is much the same, but the endopodite has commenced to deteriorate, and the exopodite is now larger. In the first pair of maxillipedes (Fig. 18, A) the protopodite has changed into two perfectly separated flattened plates, which are applied to the sides of the mouth, and are clearly jaws; the endopodite has become quite small, and the exopodite large in proportion. In front of these are the two pairs of maxillæ. The last pair of these is not very different from the first maxillipedes; but the two joints of the protopodite

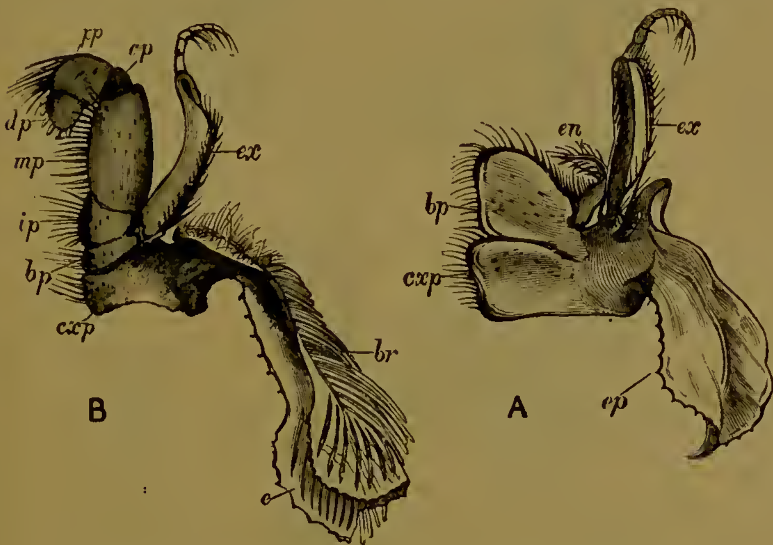

FIG. 18.—A, first, B, second, maxillipede of Crayfish. (After Huxley.) *c, ep*, epipodite ; *en*, endopodite ; *ex*, exopodite ; other letters as in Fig. 16.

podite are still more flattened and jaw-like, and each joint has become partially separated into two. The endopodite is still small, and the exopodite is fused with a flat plate, present in the appendages lying behind, and there associated with the gills (*q.v.*), the so-called *epipodite*. In the first pair of maxillæ the protopodite is all of functional importance that remains of the appendage, but there is still a small endopodite. Finally, there are the mandibles, in which the protopodite forms a massive chewing organ, to which is appended a small and jointed endopodite. We can trace, therefore, in the series of mouth appendages, a gradual change from ambulatory to manducatory limbs, brought about by the growing importance of the protopodite and lessening importance of the endopodite and exopodite. It may be mentioned that the conjoined exopodite and epipodite of the second maxilla is often called the *scaphognathite;* it serves to create a current of water through the branchial chamber, and thus to renovate the body through the oxygen absorbed by the branchiæ.

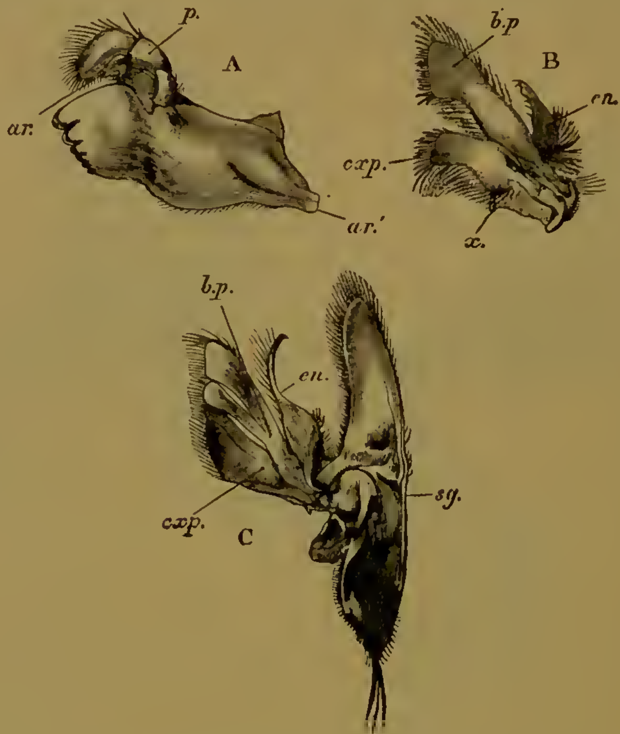

FIG. 19.—Mouth appendages of Crayfish. (After Huxley.)
A, mandible; B, first, C, second, maxilla; *p*, palp; *b.p*, basipodite; *c.x.p.* coxopodite; *en*, endopodite; *sg*, scaphognathite.

Besides the appendages that have been already enumerated, the crayfish possesses two other pairs. These are the *antennæ* and the *antennules*. The antennæ, which form the second pair of these, are shown in Fig. 20, C. Each consists of a basal piece, two-jointed, which may be compared with the protopodite of other limbs. With this articulate, firstly a scale-like structure, the *scaphocerite*, which is perfectly movably articulated, and a long, many-jointed flagellum.[1] The scale is believed to represent the exopodite, and the flagellum the endopodite.

Finally, the antennules have the form illustrated in Fig. 20, B. Each is formed of a basal piece consisting of three joints, which bears distally two approximately equally sized flagella. It is tempting to see here also a biramous limb of the typical character. But it is not clear that this comparison is justifiable, for it will be observed that the two flagella spring from the third joint, while in all other cases the endopodite and

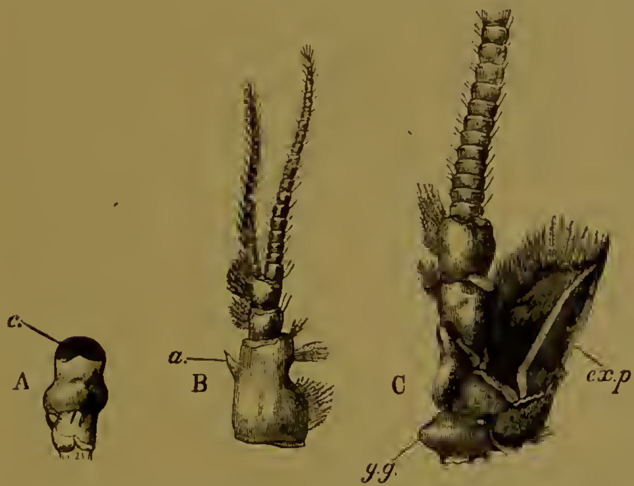

FIG. 20.—Head appendages of Crayfish. (After Huxley.)
A, eye-stalk ; B, antennule ; C, part of antenna ; *c*, surface of eye ; *ex.p*, exopodite ; *g.g*, orifice of green gland.

exopodite arise from a protopodite consisting of two joints. More probably, therefore, the bifid character of the terminal part of the antennules has nothing to do with the biramous limb, but is a simple fission or a secondarily added appendix. Some naturalists have endeavoured to show that the eye, or rather the eye-stalk, is a rudimentary appendage, consisting in this event of the protopodite only. The stalk is certainly movable; but as the structure arises from a different part of

[1] The use of the term "flagellum" for a piece composed of numerous minute joints will not be confounded with the long vibratile cilium, which, when single or in groups of very few, in Protozoa and other animals bears the same name.

the embryo to that whence the other appendages arise, it is probably not justifiable to make this comparison.

We thus see that the crayfish body consists of nineteen segments, each provided with a pair of appendages, a rostrum in front and a telson behind. That the segments are less clear anteriorly, as is the case with the earthworm, where their characters are less marked (*i.e.* absence of setæ on the first, absence of distinct septa internally, etc.); there is, in fact, by this means, a specialized anterior region—a *head* formed. The limbs are reducible to a common plan, which is modified in accordance with the varying function of the limbs.

In the course of the dissection necessary to follow the foregoing description, the organs of respiration—the *gills* or *branchiæ*—will have been noted. They are feather-like structures lying beneath the branchiostegite, and limited in consequence to the thoracic region of the body. On each side there are altogether eighteen fully developed gills, besides certain rudiments which will be referred to in due course. These gills, however, are arranged distinctly in three series, and according to their position have been termed *podobranchs*, *arthrobranchs*, and *pleurobranchs*. When the thoracic limbs (7–12 inclusive) are removed a gill will be removed also. If care is taken, only one gill will be torn away with each limb. These gills, which are attached to the coxopodites of the limbs, are the podobranchs. Each consists of a stem which bears a series of filaments on each side. The stem expands above into a lamina which is bent in the form of an open book. On the first maxillipede there is no podobranch; at least, no fully developed podobranch. There is, however, the structure already described as the epipodite. It is nearly certain that this membranous plate is a rudimentary podobranch; and these are the reasons which lead to that inference. In the first place it occupies precisely the same relations to the limb that bears it as do the podobranchs of the six following gills. Secondly, it is a longitudinally folded plate, like the lamina of the gills, and bears certain hooked spinelets upon its surface exactly comparable to spinelets borne upon the lamina of the fully developed gills. But the strongest argument is that in certain exotic crayfishes this epipodite has a few rudimentary branchial filaments.

When the podobranchs have been removed, other gills come into view. These are termed arthrobranchiæ, from the fact that they are attached to the articular membrane, to which is also attached the limbs. These gills correspond to the same appendages that bear the podobranchs; there are, however, a pair to each limb, except No. 8, which has but one—that is to say, there are eleven in all. The structure of these arthrobranchiæ differs from that of the podobranchiæ in that there is no lamina; the stem which bears the gill filaments is not expanded into the folded plate characteristic of the podobranchs.

Finally, the last thoracic limb (No. 13 of the entire series) bears a single gill, which is attached at a level above that of the podobranchs and arthrobranchs—to the epimeron, in fact. This is the pleurobranch. In front of it, and occupying a similar position with regard to the two limbs in front, is a tiny unbranched filament which is believed to represent a rudimentary pleurobranch: from the fact that it occupies a similar position, and—more important—from the fact that in various exotic crayfish there are fully developed pleurobranchs corresponding to the limbs in question. The rudiment, such as it is, may be compared to the stem of the otherwise missing gill.

It is convenient for the purposes of a ready comparison with the gills of other crayfishes to express the arrangement of the gills as a formula :—

Appendages of segt.	Podobr.	Arthrobr.	Pleurobr.
6.	0 (ep.)	0	0
7.	1	1 + 0	0
8.	1	1 + 1	0
9.	1	1 + 1	0
10.	1	1 + 1	0
11.	1	1 + 1	*r*
12.	1	1 + 1	*r*
13.	0	0	1
	6 + ep. +	6 + 5 +	1 + 2*r* = 18 + ep. + 2*r*

When the body of the crayfish is opened by dissecting off

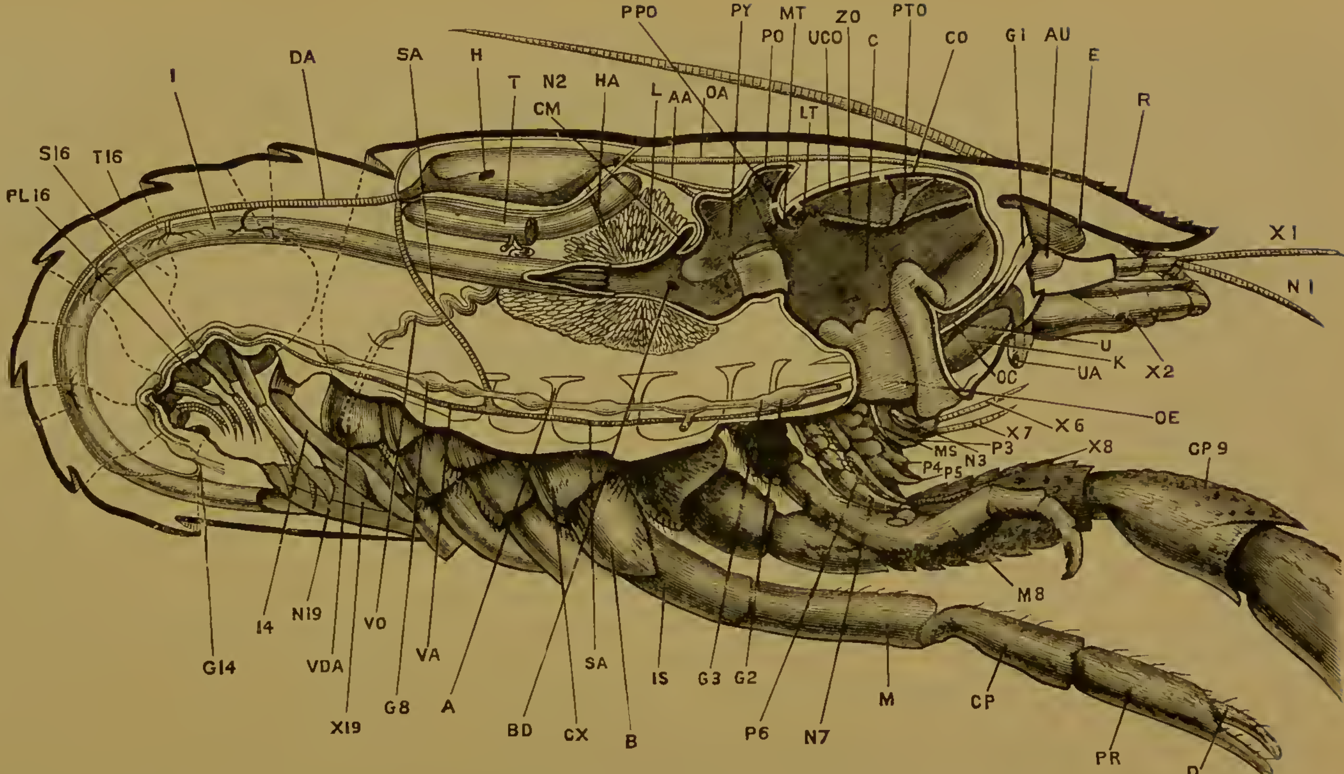

Fig. 21.—General dissection of the Crayfish. (After Marshall and Hurst.

A, endophragmal skeleton; AA, antennary artery; AU, auditory sac; B, basipodite; BD, aperture of bile duct; C, cardiac chamber of stomach; CM, cœcum; CO, cardiac ossicle; CP, CP9, carpopodites; CX, coxopodite; D, dactylopodite; DA, dorsal abdominal artery; E, eye; G1, supra œsophageal ganglia; G2–14, ventral chain of ganglia; H, lateral ostium of heart; HA, hepatic artery; I, proctodæum; IS, ischiopodite; K, green gland; L, liver; LT, lateral tooth; M, meropodite; MS, metastoma; MT, median tooth; N, endopodite; OA, ophthalmic artery; OC, circumœsophageal commissure; OE, œsophagus; P, protopodite; PL, pleuron; PO, pyloric ossicle; PPO, prepyloric ossicle; PR, protopodite; PTO, pterocardiac ossicle; PY, pyloric stomach; R, rostrum; SA, sternal artery; S, sterna; T, testis; T16, tergum; U, ureter; UA, its aperture; UCO, urocardiac ossicle; VA, ventral artery . . .

the shell above, the interior of the body is seen to be almost entirely filled with the various viscera. Chinks of an irregular form will be visible between the white masses of the muscles; but there is no spacious cavity like that of the frog or earthworm. In the crayfish, in fact, the body cavity is greatly reduced, and what there is in the way of irregular spaces is not cœlom, but is made up of blood spaces in communication with the heart. There are, however, perhaps traces of the cœlom in two places: in the interior of the generative gland and at the extremity of the renal organ. But these matters will be entered into when the organs in question are described. The *muscular system* of the crayfish is enormously developed. The muscles form masses which pass from segment to segment and between the various joints of the appendages. Their detailed description, however, would occupy more space than can be allowed here. When the body is opened from above, the first organ that comes into view, commencing from above, is the *heart*. This is a thick-walled sac of somewhat hexagonal form. It lies in a thin-walled sac, which is often—but erroneously—called the pericardium. The strong muscular wall of the heart is perforated by six apertures, the *ostia*. Of these two are dorsal, two lateral, and two more ventral. They permit a free entry of blood from the enveloping sac into the heart; but the valves with which they are provided internally prevent the egress of blood from the heart into the investing sac. This so-called pericardium cannot be compared with the pericardium of the anodon or the frog, for several reasons. In the latter animals the pericardium is a portion (in anodon practically the whole) of the cœlom, which has no relation to the vascular system. In *Astacus* the so-called pericardium is to be regarded simply as a number of fused veins whose originally separate orifices into the heart are the existing ostia. It is better to term it the "auricle."

It is an auricle opening into the ventricle which happens incidentally to envelop it. The pericardium of the other animals mentioned is not connected by openings with the heart which lies in it. The accompanying diagrams may serve to explain the way in which the peculiar auricle of the crayfish's heart arose.

From the ventricle spring a number of arteries, which are delicate and transparent, and not readily visible until they are injected with some coloured fluid. In the middle line in front is the ophthalmic artery, which runs in a straight course to the eyes. On either side of this is an antennary artery. Each of these supplies the antennæ, antennules, and the green gland of its own side. A little further back there springs from the ventricle on either side an hepatic artery, which, as its name implies, goes to the liver. The stomach is provided with blood from the antennary artery. From the posterior margin

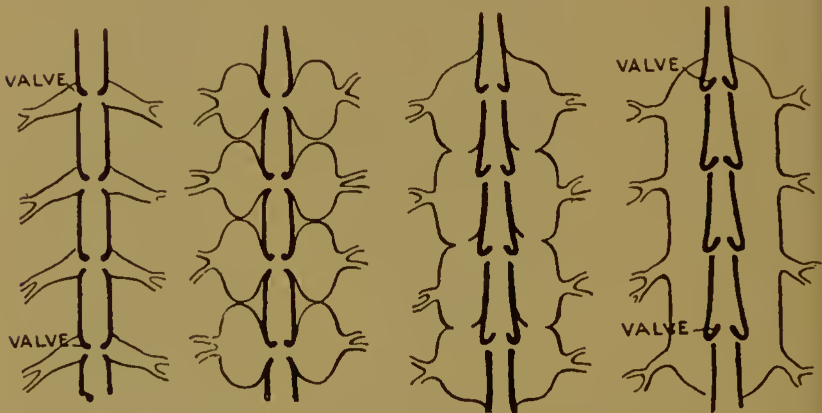

FIG. 22.—Diagrams to illustrate the formation of the "pericardial sac" of Arthropods from the fusion of veins with originally separate openings. (After Lankester.)

of the ventricle arise two arteries; one of these, called the superior abdominal artery, runs straight along the surface of the intestine, giving branches to it and to the adjacent muscles; the other descends obliquely downwards, and is known as the sternal artery. It passes between two of the thoracic nerve ganglia, and divides immediately into a forwardly running and a backwardly running artery. These give off a regular series of branches, which between them supply the appendages and the ventral musculature of the body. The veins of the crayfish are largely sinuses, *i.e.* more or less wide and irregularly shaped channels. The blood in these enters a particularly large sinus lying on the ventral side of the body; and from this the blood passes by a series of veins to the gills, and thence by another series to the heart. The *blood* of the crayfish is a colourless fluid which contains a number of floating corpuscles amœboid in form.

The *alimentary tract* of the crayfish consists of a straight tube, which is not of the same character throughout, and of a pair of large glands, generally called the liver, which open into it.

The first part of the alimentary canal is the *œsophagus*, which opens externally by the mouth, and passes upwards from that point to open into the large stomach. The *stomach* is formed of two compartments, an anterior cardiac and a posterior pyloric portion. The cardiac portion has its inner surface thickened by a number of strong calcified pieces, which together form a masticating apparatus for the animal's food. The various ossicles of this stomachal skeleton are so arranged that three specially hard "teeth," borne upon the extremities of some of the ossicles, can be made to converge in the middle line, and effectually break into pieces any hard particle of food. The general arrangement of these various ossicles and teeth may be appreciated by an inspection of the accompanying diagram (Fig. 21); their action can be seen by pulling upon the two ends of the apparatus of the stomach with two forceps. The pyloric part of the stomach is provided with a number of more delicate plates furnished with stiff hairs, the whole forming rather a sifting than a crushing organ. Immediately upon the stomach there follows a very short tract of gut, which differs from the preceding and from the part which follows it, in having soft walls; it is not lined, as is the rest of the canal, by a thick cuticular lining. This *mesenteron* is produced dorsally into a short *cæcum*, and it receives the ducts of the two *hepatic glands*. After this comes the *hind gut*, which has a longitudinally folded cuticular lining; it opens on to the exterior by the anus.

The *excretory organs* of the crayfish consist of a single pair of glands known as the *green glands;* they are placed in the head region of the body, and open on to the exterior by a pore placed upon the basal joint of the antenna upon a tubercule which that joint bears. The gland, which owes its name to its bright green colour, has been proved to be excretory in function, to contain guanin, an excretory product. The gland consists of a coiled tube opening into a terminal sac, which itself, as already stated, opens on to the exterior. A small "end sac" has been described in connection with the excretory organ, which has been regarded as a remnant of cœlom; in this case, therefore, the green gland of *Astacus* will be comparable to a nephridium of *Lumbricus*, in so far as it is a glandular tube, opening at the one hand into the cœlom, and at the other on to the exterior. If this structure be not a vestige of cœlom

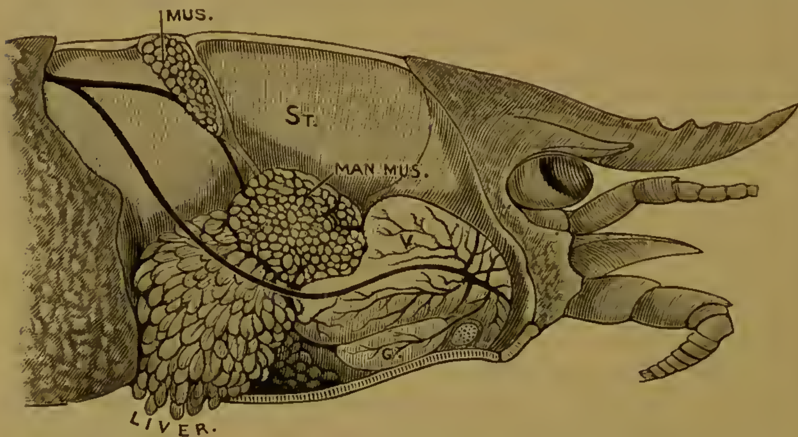

FIG. 23.—Dissection of anterior end of Crayfish, to show relations of green gland. (After Marschall.)

V, vesicle of green gland, G, glandular portion; ST, stomach; MAN. MUS, mandibular muscle.

there is still no final difficulty in comparing the green gland with a nephridium; for in an animal in which the cœlum is so largely aborted as it is in *Astacus*, it might be very well supposed that the nephridial funnel had disappeared also.

If there be some difficulty in comparing the excretory system of the crayfish with that of the earthworm, there is no difficulty in comparing the nervous systems of the two animals. In the crayfish we have precisely the same plan of central nervous system. There are a pair of supra-œsophageal ganglia just below the rostrum; from these arise circum-œsophageal commissures, uniting behind the œsophagus to form a chain of ganglia extending through the body. This chain consists of six separate pairs of ganglia in the cephalothoracic region, and six in the abdominal. It will be observed that in the abdominal region there is an exact correspondence between ganglia and segments, but not in the cephalothoracic. As, however, there is some fusion between the originally separate segments of the anterior region of the body, it is hardly surprising to find that this characteristic has extended itself to the ganglia of the nervous system. From the circum-œsophageal commissure and from the cerebral (supra-œsophageal) ganglia arise three

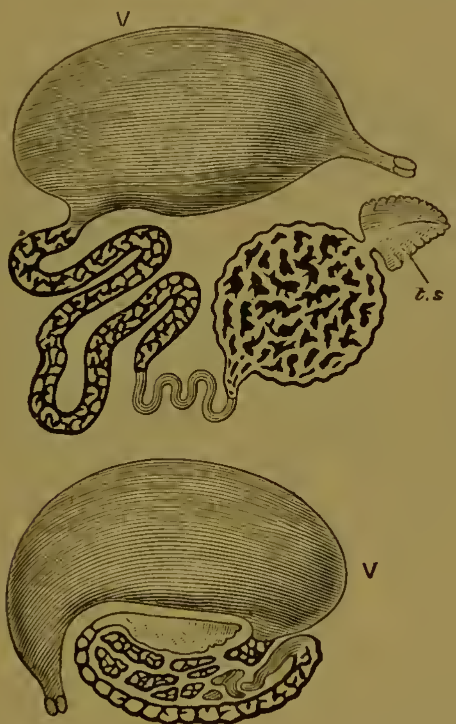

FIG. 24.—Green gland of Crayfish. (After Marschall.)
The upper figure represents the apparatus dissected out. v, vesicle; *t.s*, terminalsac; between them lies the glandular part.

nerves which unite to form a trunk, which supplies the anterior part of the alimentary tract, and is known as the *visceral nervous system.*

The crayfish is well off for *sense organs.* The *eyes* have been already mentioned. They have a complex structure, equally complicated with that of the eye of a man, but of a different character. It will not be possible to describe them here. The *olfactory organs* appear to be represented by certain hairs upon the antennules. Other hairs which cover the body and the appendages seem to be of a *tactile* nature; the *auditory organ* is a sac in the anterior of the basal joint of the antennules, with an opening to the exterior, and a lining of delicate *auditory hairs*, between which float tiny particles—the *otoliths.*

The crayfish is of two sexes: there are males and females. Externally, the two sexes can be readily distinguished. In the

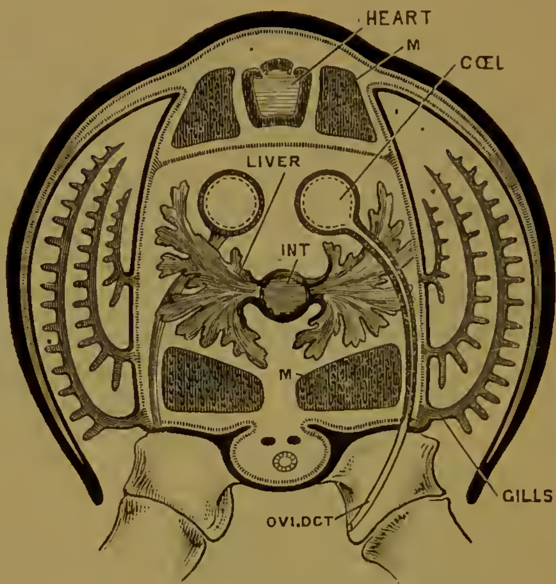

FIG. 25.—Diagrammatic transverse section of Crayfish. (After T. J. Parker.) CŒL, cavity of gonad; M, muscles; INT, mesenteron with liver appended.

female the abdomen is broader and deeper in its excavation below; this serves to pack away the eggs, which when extruded are attached to the swimmerets. In the two sexes the first two pairs of abdominal appendages are modified in the way that has been already described. In the male the *reproductive organs* open on to the last pair of thoracic appendages; in the female on to the last but two. The "gland" itself in both sexes is a Y-shaped mass, white in the male and the immature female, brown in the more mature female. It is a hollow structure, and the cavity communicates with the lumen of the duct, which carries the generative products to the exterior. These ducts are long and much coiled in the male; short in the female. It is believed that the cavity of the generative gland is cœlomic in nature. This conclusion has been arrived at from a consideration of the formation of the gonad in animals. The gonads are, as already pointed out to be, regarded as local proliferations of the cœlomic epithelium, either restricted to a limited area, as in the earthworm, the vertebrate, etc., or spreading through the whole, or nearly the whole, of the body, as in certain marine worms. If this portion where the generative tissue is formed be separated from the rest of the body, and the cœlom obliterated elsewhere than here, we arrive at a structure like that of the crayfish, where, moreover, it will necessarily follow that the oviducts, or sperm ducts, opening into this intra-gonadial region of the cœlom will get the appearance of being merely prolongations of the gonads themselves (see also p. 159).

CHAPTER V.

THE COCKROACH (BLATTA ORIENTALIS).

The common **Cockroach** of our kitchens is the one that is selected as the type for the present chapter; but an American species, *Periplaneta americana*, is really a better animal for dissection, as it is larger than the former species, which originally came to us from the East. The most important difference between the two is, that *P. americana* is winged in both sexes, while in *Blatta orientalis* it is only the male which has fully developed wings.

The cockroach belongs to the same great division of the animal kingdom as does the crayfish. It is an arthropod; but it breathes by means of tracheæ instead of gills, and is referred, on that and other accounts, to a separate division of the Arthropoda, the Tracheata, in which division it is a representative of the class Insecta.

As in the crayfish, the body is clearly segmented, and the segmentation is more obvious in the abdominal than in the thoracic or cephalic regions. There is a plain division between head and thorax, a narrow "neck" joining and marking the line of division between them.

It is believed, from a consideration of the appendages, which will be considered presently, that the head consists of three fused segments, lying behind the mouth, and a prostomium, comparable to that of the earthworm, lying in front of it. There are, however, no indications in the sclerites, which form the exoskeleton of the head, that this is probably the case. The *head*, which is carried at right angles to the thorax, its appendages lying therefore behind it instead of below it, is covered by a wide sclerite above (the *epicranium*), divided by a Y-shaped suture into right and left halves; each fork of the Y terminates in a round soft spot of unknown function. In front of and below this plate is the *clypeus*, with which articulates still further forward the upper lip, or *labrum*—not an appendage. At the sides of the head are two other pieces, the *genæ*. Above the genæ are the conspicuous compound *eyes*, black in colour, owing to the contained pigment. The *thorax* evidently consists of three segments: each has a dorsal plate, the *tergum;* a ventral plate, the *sternum;* and two smaller elements, the *episternum* and *epimeron*. From the *mesonotum* and *metanotum*, as the terga of the second and third segments are called (the first being *pronotum*), arise *wings*. The first pair of these are stiff, and serve as covers (tegmina) for the second pair, which are delicate, and folded when not in use. These wings are processes of the terga, and may so far be compared to the branchiostegite of the crayfish. The abdomen is made up of certainly ten, and possibly eleven, segments; the eleventh is a pair of plates which lie on either side of the anus. Each segment has a tergal and a sternal plate, connected by soft membrane. The segments differ somewhat in size, the eighth and ninth being very small, and usually hidden by the seventh in the female of *B. orientalis*. Thus the entire body of *Blatta* is made up of not more than seventeen segments.

The *antennæ* are not equivalent to the following appendages; they arise from the prostomium, and are therefore probably the equivalents of cirri, which are found arising from the prostomium in many aquatic worms. It is true that in the crayfish both antennæ and antennules are preoral in position; but a consideration of the structure of the cerebral ganglia which supplies them with nerves has led to the conclusion that it is a compound structure containing not only the true cerebral ganglia, but a pair of primitive postoral ganglia, which have moved forwards. Thus, the first pair of appendages in *Blatta* are the mandibles; it is these that correspond to the antennules of the crayfish. The *mandibles* are strong and jaw-like, consisting of a basal piece only. The next appendage can be homologized with the typical Crustacean limb, as already explained.

Each consists of a protopodite and of an endopodite and exopodite. In the first of these—the *first maxillæ*—the proto-

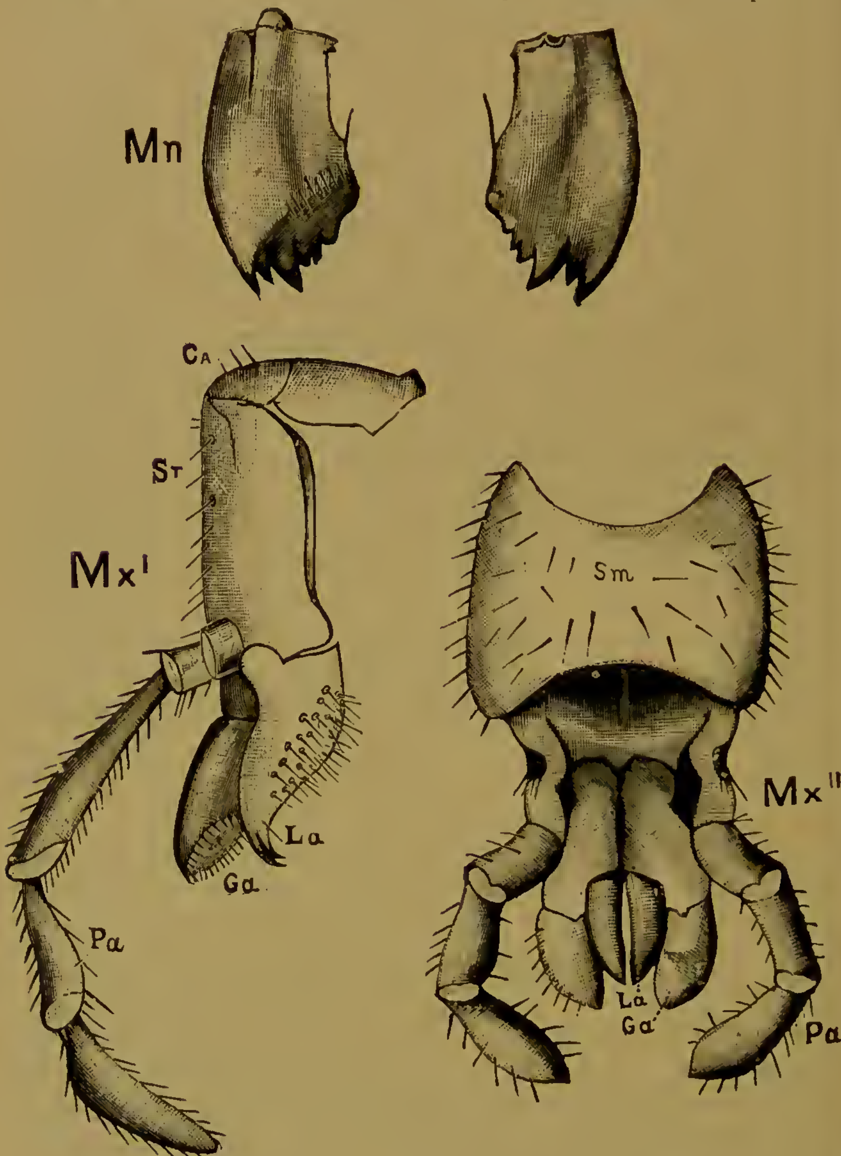

Fig. 26.—Mouth appendages of Cockroach. (From Miall and Denny.)

Mn, mandible; Mx', first maxilla; Mx'', fused second maxillæ; Ca, cardo; St, stipes; *La*, lacinia; *Ga*, galea; *Pa*, palp; *Sm*, submentum.

podite has the usual two joints, the *cardo* and *stipes*; with the latter articulates, first, the endopodite, divided longitudinally into two pieces, an inner *lacinia* and an outer *galea.* The exopodite is a five-jointed palp. The *second maxillæ* have their protopodites fused to form a basal piece, divided into a *submentum* above and a *mentum* below; the endopodite is divided into a *paraglossa* (or lacinia) and a galea; while, as in the first maxillæ, the exopodite is a palp, but three-jointed.

The three pairs of thoracic appendages (whence the term "Hexapoda" for insects) are walking limbs with five joints apiece and a pair of terminal claws. The abdomen has no obvious appendages; but the *cerci* borne on the tenth segment and the anal styles of the male on the ninth may be vestiges of such structures.

The remaining characters of importance to be noted without dissection are the orifices of the tracheæ and of the scent glands. The former—the *stigmata* or *spiracles*—are present to the number of nine or ten pairs—two upon the thorax, and the rest upon the abdomen. They are widish orifices, guarded by hairs, which lie laterally between the segments, and lead into the tracheal tubes, which ramify in the interior of the body, and will be described presently. The scent glands, which have been only lately discovered, are two pouches lying on the dorsal surface of the fifth abdominal segment, between this segment and the next behind.

The *heart* is a dorsally situated tube which ends blindly behind, and is prolonged into an aorta anteriorly. The heart has a series of paired lateral ostia, and lies in a blood space like that of *Astacus*. But the circulation generally of *Blatta* is less " finished " than that of *Astacus*. In addition to the pulsating sinus which envelops the heart, there is a ventral sinus, also pulsating, which covers the nerve-cord.

The *respiratory organs* are the tracheæ. These are tubes lined with a spirally thickened chitinous membrane, which ramify through the body, as shown in Figs. 27 and 28. Air is thus carried to every organ; and this complete aeration perhaps accounts for the imperfection of the circulatory system, which is usually the only, or nearly the only, way in which the organs and tissues can receive their supply of oxygen and get rid of their carbonic acid.

A considerable portion of the space within the body is taken up by the *fat body*. This is an irregular ramifying mass

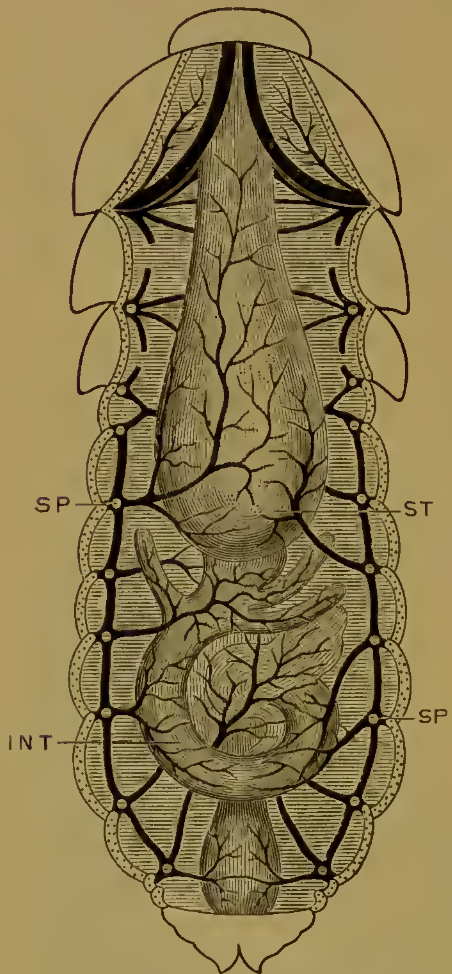

FIG. 27.—Tracheal system of Cockroach. (After Miall and Denny.)
SP, spiracles; ST, stomach; INT, intestine.

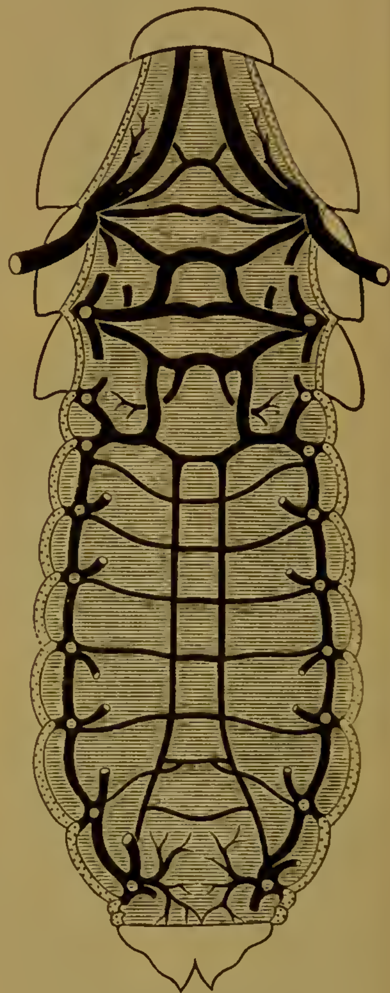

FIG. 28.—Tracheal system of Cockroach after removal of alimentary tract. (After Miall and Denny.)

of white tissue made up of cells in which fat globules are deposited. It has also been found to contain uric acid, and therefore it seems to play some part in excretion

The *alimentary canal* is rather complicated. As in the crayfish, there is a large anterior section lined with chitin, and termed the stomodæum; a large posterior section, also lined with chitin, and termed the proctodæum; and a short middle section, the mesenteron. The mouth leads through a short œsophagus, gradually widening into a large crop; this is followed by a thick-walled gizzard, with six large cuticular teeth. Then follows the short mesenteron. The proctodæum is divisible into a short ileum, a long colon, and a wide terminal rectum whose inner walls are raised into a number of ridges. The alimentary tract is furnished with a number of glands.

Firstly, the *salivary glands*, which are present on each side of the crop to the number of two. They are white diffuse glands, and between them lies a bladder, the *salivary receptacle.* The ducts of all unite to open into the mouth cavity. Opening into the *mesenteron* (sometimes called the "chylific stomach") are the *hepatic cæca*, blind tubes, seven or eight in number. Finally, there are the *malpighian tubes*, sixty or more, which open into the commencement of the intestine. These, however, are not glands supplying any fluid used in digestion; they are excretory in function, and uric acid has been found in them. It is doubtful whether these structures can be compared with the excretory organs of other animals. There are, however, a few facts which render a comparison possible (see p. 158). But it is necessary, in the mean time, to dwell rather upon their unlikeness to the excretory organs of other animals.

The *nervous system* is constructed precisely on the plan of that of *Astacus.* There is a supraœsophageal ganglion connected by a circumœsophageal commissure with a ventral chain of three thoracic and six abdominal ganglia, besides a subœsophageal ganglion in front, which seems to represent three fused ganglia, as it supplies the three first postoral pairs of appendages. There is also a visceral nervous system, consisting of a small frontal ganglion, which is connected with the circumœsophageal commissure by two nerves, and which gives off backwards a single nerve, running back along the crop to a small ganglion on the dorsal surface of the crop, whence two nerves run still further back.

The *reproductive organs* are elaborate. In the male the *testes* lie imbedded in the fat body. From them arise two *vasa deferentia*, which open into the wider and muscular *ejaculatory duct*. At the junction of the two are the *vesiculæ seminales*, termed collectively the "mushroom-shaped gland." The genital aperture, which is upon the last segment, just below the anus, is provided with a complex series of chitinous outgrowths, the *gonapophyses*.

In the female each *ovary* consists of eight tubes, which unite to form the oviduct; the two oviducts open together upon the eighth sternum. Further back, upon the ninth sternum, opens the *spermatheca*, which consists of a pear-shaped pouch and a narrow coiled tube; the latter seems to be the equivalent of a second spermatheca. On the following segment open the much-branched *colleterial glands*. The female is furnished, as is the male, with gonapophyses.

CHAPTER VI.

THE METAMORPHOSES OF INSECTS.

THE young **Cockroach** is hatched from the egg in a condition in which it hardly differs from the parent insect. It is simply paler in colour; its eyes are smaller, with fewer facets; the wings are not developed, and the reproductive organs are immature. The change from the newly hatched insect to the reproductive adult is simply a question of growth. This is naturally accompanied by several moults, of which there appear to be seven.

On the other hand, there are many insects which leave the egg in a condition only very remotely resembling the parent form. There is a vast difference between the "woolly bear" and the "tiger moth," into which it is ultimately converted. Moreover, in this case, the transition from larva to adult is not a gradual one. There is an abrupt change from the caterpillar to the chrysalis, from the chrysalis to the moth. To these changes the term "metamorphosis" is applied; and insects which exhibit such metamorphoses are termed "metabolous" to distinguish them from the "ametabolous" cockroach. Among metabolous insects are the neuroptera (dragon-flies), hymenoptera (ants, bees, and wasps), the diptera (two-winged flies), and lepidoptera (butterflies and moths). In order to illustrate the nature of this metamorphosis, we shall select an example from each of the last two classes of insects; the silk-worm will serve as a type of the lepidoptera, the blow-fly of the diptera.

The life-history of the **Silk-worm** (*Bombyx mori*) is briefly this: From the egg emerges a caterpillar, which feeds upon leaves, and continues to grow until it is immensely larger, but not different in structure from the minute newly hatched larva. It then becomes quiescent, and secretes a dense chitinous coat, which covers its nearly motionless body. This is the pupa stage, which is further protected by the cocoon, the well-known silk produced by the larva from certain glands, which entirely envelops it. From the pupa, after a certain lapse of time, emerges the moth—the imago, or perfect insect, as it is called.

The caterpillar is a segmented creature with so great a likeness between the successive segments that a vermiform appearance results. Hence the general term of "worm" popularly applied to insect larvæ, especially to those with no legs. The head of the caterpillar has a pair of small antennæ, sessile eyes (differing in structure from the compound faceted eyes of the adult), a pair of strong biting mandibles, and a plate behind the mouth which corresponds to the next two pairs of appendages fused together. After the head follow three segments, which constitute the thorax; each of these has a pair of jointed walking legs. Then comes an abdomen of ten segments (possibly with a terminal eleventh). Not all of these segments have limbs, but the third to the sixth, and the last, have fleshy "prolegs" armed with terminal hooks.

When the larva reaches a certain size it becomes a pupa. The pupal stage is quiescent; the pupa, when touched, will exhibit movements, and in many moths which enter the pupal stage in burrows in wood the pupa moves towards the surface just before the time of emergence of the imago. But, broadly speaking, the pupal stage is quiescent. During this period of rest important changes take place. The tissues of many of the organs break down, and are reconstructed into the definitive organs of the imago; to this remarkable histological process the term "histolysis" has been applied. The pupa much more resembles the perfect insect than it does the larva. The appendages of the imago, its wings, and compound eyes, are visible in the pupa, while the external reproductive orifices are visible by marks. The number of segments in the pupa appears to be the same as in the larva, *i.e.* certainly ten abdominal segments and three thoracic.

The hard chitinous integument which envelops the pupa is not the larval skin; it is formed by the hardening of a sticky fluid thrown off at the moment when the caterpillar skin is also thrown off. If a mature caterpillar be dissected just before this period, the various organs of the pupa, wings, limbs, etc., can be seen to be perfectly free. After a longer or shorter period of rest the perfect insect breaks through the cuticle of the pupa, and escapes.

On reviewing the life-history of this moth it will be observed that a great difference in the way of life accompanies the more complicated metamorphosis. In the cockroach, the young leads practically the same kind of life as the adult. The difference between them is hardly more than that the earlier stages are devoted to growth, the latest to reproduction. This difference in way of life is also seen between the caterpillar and the moth—in a more marked fashion, indeed, for the feeding of a perfect insect is often practically nothing at all; but, whereas the caterpillar eats leaves, the moth sucks the juices of flowers, and has, as a consequence, a totally different arrangement of the mouth organs. It is this diversity of mode of life which has led—in the opinion of some—to not only the extraordinary difference between larva and imago, but also to the existence of the quiescent pupa. To change the biting parts of the caterpillar's mouth for the sucking proboscis of the moth would necessitate, if the development were gradual, a series of intermediate stages, which would not be serviceable in either capacity. Hence, during a quiescent period, in which no food is taken, and during which the animal is protected by the silk cocoon, the changes could be, and are, brought about.

The **Blow-fly** (*Musca vomitoria*) has a series of metamorphoses, which do not differ greatly from those of the silk-worm. From the egg is produced a larva, which differs from that of the silk-worm in being apodous; the limbs are absent. The pupa, into which the maggot turns, is again different, in that its outer brown chitinous case is not a new formation, but the shrunken skin of the larva. Within this skin the process of breaking down of the tissues goes on rapidly. The generative organs, however, appear to be continuous with those of the larva, where they may be recognized as rudiments, as in the caterpillar of the moth. Coincidently with this histolysis, or breaking down of tissues, occurs an histogenesis, or building up of tissue. This largely takes place from the so-called "imaginal discs," which are buds of the outer layer; but other of the internal organs are reproduced by reformation of the disrupted tissues of the corresponding larval organs. It seems to be mainly the external parts that are formed from the imaginal discs.

CHAPTER VII.

THE POND MUSSEL (ANODONTA CYGNÆA).

The common **Fresh-water Mussels** really belong to two genera; but those referable to *Anodonta* are most usually made use of for purposes of dissection, and most current descriptions refer to that genus. It contains two species that are found in this country, *A. cygnæa* and *A. anatina*. They both occur in lakes, ponds, and canals, where the water is sluggish. The animal lies buried in the mud at the bottom of such a piece of water, with the narrower end imbedded in the mud and the broader end freely emerging. A current of water is kept up by the action of cilia through the posterior end of the shell, so that minute organisms are brought towards the mouth at the opposite extremity. At the same time the current of water serves for the aeration of the gills. The anodon is of two sexes, and the males cannot be distinguished externally from the females, as has been often asserted to be possible. So rare, too, are the males, that the females may possibly also develop male products; but there is no positive evidence upon the point. Out of fifty anodons dredged, Mr. Latter found only two males. The life-history of the anodon is interesting. The eggs are shed into the external, not into the internal, gill; the walls of the gill secrete a mucous matter, in which the developing eggs are held. The young are hatched from the eggs in a stage which has been termed *Glochidium*, on account of the fact that these young organisms were regarded originally as independent organisms. The glochidium has the valves of its shell armed each with a long curved spine, and the foot secretes a bunch of filaments, the *byssus*. This byssus serves to moor the young to the gill-plates; it has the interesting feature of being the equivalent of the byssus of the sea-water mussel, by means of which that mollusc can hang on to piles of wood, etc., a fact which seems to show that the anodon is descended from a byssus-bearing bivalve. The young glochidia are ultimately expelled from the sheltering gill cavity, and then fall to the bottom of the pond or lake, where the parent form happens to be living. They cannot swim at all, but lie at the bottom on the valves of the shell, with the byssus filaments streaming upwards. With these, and with the nipping valves of the shell, they fasten on to some small fish, such as a stickleback. The glochidia appear to have a very keen appreciation of the presence of small fish. On one being introduced into water swarming with glochidia, the latter were observed violently to close and open the valves of their shell; had the fish swum near enough they might have succeeded in laying hold of it. The advantage of this power of adhering to a fish is that the young glochidium is carried about, and the currents due to the movement bring particles of food within its reach.

The adult anodon, like the glochidium, is enclosed in a two-valved shell. But the *shell* of the adult arises underneath that of the larva, and is marked by a series of lines running parallel with the long axis of the shell, which indicate its growth. These lines about the middle are slightly curved upwards, an effect which is due to the sharp teeth of the glochidium shell impinging upon the soft and growing shell beneath, and checking its growth at that point. The bivalve shell is composed of two separate halves, which are joined near the summit, the *umbo*, by an elastic hinge, which is stretched during life by the action of the great *adductor muscles*, but which after death is relaxed, and thus suffers the shell to gape. On the inside of the shell are to be seen the strong impressions of the two adductors, and of three other muscles, *two retractors* and a *protractor* of the foot, which muscles serve, as their names indicate, for the protrusion and retraction of the foot.

Conchologists often distinguish between the shell of a mollusc and the "animal." This is, it is hardly necessary to point out, an unfortunate use of language, as it implies in a way that the shell is an adventitious structure, like the case of a caddis-worm. The shell is a secretion of the epidermis of the mussel, just as is the shell of the crayfish. So far the two structures are strictly comparable; and the fishmonger who broadly classifies marine articles of food into fish and shell-fish, is not committing so gross a zoological solecism as might be. The part of the body which underlies and forms the shell is known as the *mantle*: it is simply a fold of the body drawn out so as to cover over the foot and gills. The

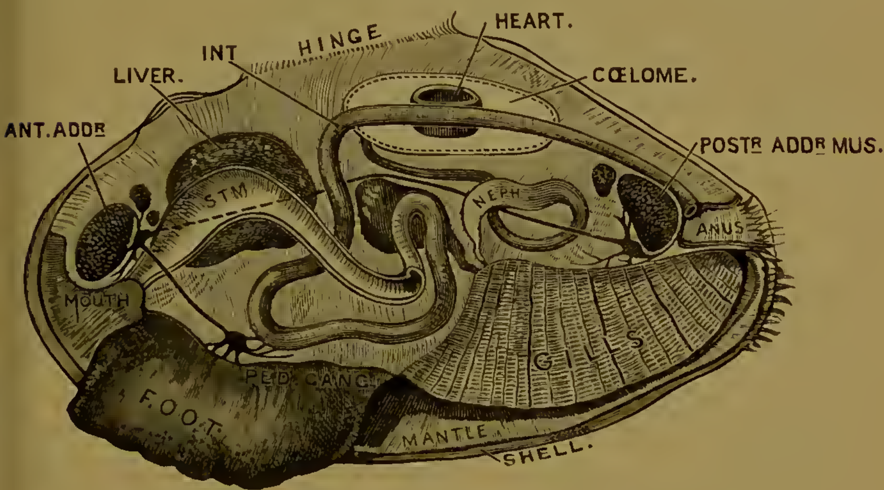

FIG. 29.—Semi-diagrammatic representation of a dissection of Anodon. (Partly after T. J. Parker.)

N.B.—The word ANUS is placed in cloacal cavity. The parieto-visceral ganglia lie below posterior adductor.

same thing has happened as in the crayfish; there there is also a fold of skin drawn out, which secretes the branchiostegite. At the posterior end of the body the two mantle-flaps become joined so as to divide an upper *exhalent orifice* from a lower *inhalent orifice*. The edges of the mantle at the latter are fringed with stiff papillæ, or tentacles. When the mantle-flap of one side of the body is removed, the structures shown in Fig. 29 are brought into view. The mantle-flaps, like the gills which are now evident, are dependences of the body itself, which is divided into a dorsal softer part, containing the viscera, and a muscular projection below and in front, which is termed the *foot*. This latter is the organ of progression, and in some lamellibranchs is so active in its movements that the animal can execute considerable leaps; this is the case with the common cockle. The movements of anodon, however, are lethargic. The most prominent organs seen are the *gills*, which have a fenestrated, lattice-like appearance; they are posteriorly continuous with the septum already spoken of, which divides the inhalent from the exhalent orifice at the posterior end of the body. Each of the two gills of each side of the body is really a bag which, in the case of the outer gill, is attached along both its edges to the body-wall; the inner gill, on the other hand, is open at various points, the inner lamella not being continuously attached to the body-wall.

In front of the gills, and at the sides of the mouth-opening, which latter lies above the foot, are a pair of ribbed flat plates, not unlike the gills in colour and appearance; these are the *labial palps*. The only other structures which are visible without further dissection are the various muscles already spoken of in describing their impressions upon the shell. If the two lamellæ of the inner gill be widely separated by cutting through the inner lamella and turning back the cut edge, the openings of the renal organs and the generative gland will be found close to each other. These apertures lie upon the body-wall between the attachments of the two lamellæ of the inner gill.

The *alimentary canal* of the mussel is simple. The *mouth*, just behind the anterior adductor, leads into a short *œsophagus*, which in its turn opens into a somewhat globular *stomach* (STM), into which debouch the bile-ducts, carrying thither the secretion of brown and much-branched *liver*. The *intestine* (INT) coils in the substance of the upper part of the foot, and then, rising towards the dorsal surface of the body, runs a straightish course through the pericardial cavity to the *anus*, which is placed at the end of a slight papilla in the exhalent chamber.

The *pericardial chamber* is so called on account of the fact that it lodges the heart. It is practically all that exists of the *cœlom* in this animal, which is thus much reduced as compared with the earthworm, or with a vertebrated animal. The *heart* consists of a thick-walled ventricle, which is coiled round the intestine, with which communicate two thin-walled auricles, and from which arise two main arteries, one anterior and one posterior. The cœlom thus conforms to the cœlomic cavity of other animals (cf. earthworm, frog), in that (1) it contains various viscera—in the present case the heart and a part of the alimentary canal only; (2) it communicates with the exterior

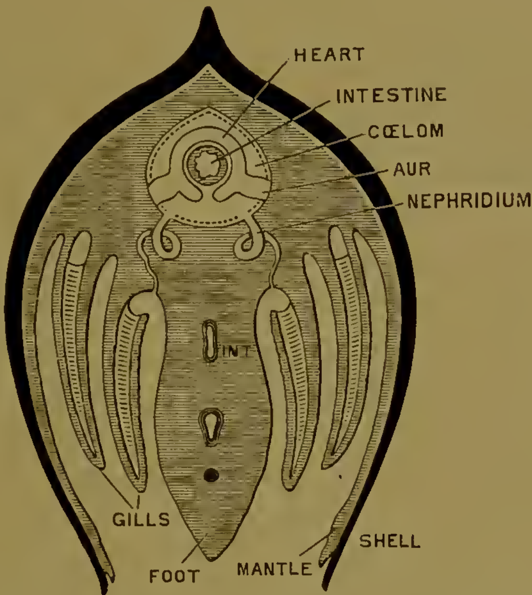

FIG. 30.—Diagrammatic transverse section of Anodon. (Partly after T. J. Parker.) INT, intestine in foot; AUR, auricle.

by means of secretory tubes, the organs of Bojanus, which are the kidneys; (3) the third character of the cœlom is not apparent in the mussel, for the gonads are removed from the cœlomic wall, and have come to lie in the thickness of the body, whence special ducts convey their products to the exterior.

The *organs of Bojanus*, or kidneys (Fig. 29 NEPH, and Fig. 30), already referred to, are the precise equivalents of the nephridia of the earthworm. Each is essentially a tube, opening, on the one hand, by an orifice into the pericardium (= cœlom), and by another orifice on to the exterior of the body. This tube, as is also the case with the nephridia, is separable into a glandular portion which is thick-walled and brownish in colour, and a vesicle, or ureter, which is comparable to the terminal vesicle of the nephridium of *Lumbricus*. The *nervous system* consists of three pairs of ganglia; of these the cerebral lie just under the skin above the mouth, and just in front of the protractor muscle. The two ganglia are connected by a fine commissure of nerve-threads lying above the mouth cavity. Each ganglion is also connected by a connective with the pedal ganglia in the foot, situated at the point shown in the diagram (Fig. 29), and by other connectives with the parieto-visceral ganglia lying beneath the posterior adductor. The ganglia are especially conspicuous on account of their orange colour.

CHAPTER VIII.

THE SNAIL (HELIX POMATIA, HELIX HORTENSIS, ETC.).

THE best snail for dissection is (on account of its large size) the so called " Roman snail." But if this cannot be conveniently obtained, the common **Garden Snail**, *Helix hortensis*, will do. The snail belongs to the same great group as the Swan mussel; but whereas the latter is bivalve, symmetrical, unisexual, and aquatic, the snail is univalve, asymmetrical, terrestrial, and hermaphrodite. It has, moreover, a distinct head, from which the tentacles bearing the eyes protrude, and is on this account placed in a separate division of the Mollusca, the Cephalous Mollusca. To prepare the snail for study, it is best to kill by drowning. A number of snails should be placed in a glass vessel, upon the top of which a glass plate can be placed so as to shut out the air. If the glass vessel be then completely filled with water, the snails immersed and the cover placed upon it, they will be found, after twelve or fifteen hours, dead, and in a fully extended condition.

Before dissecting the animal there are a number of external characters that should be noted. When the body is fully extended, it is seen to be divisible into two regions: the muscular *foot*, with the *head* at the anterior end, and the *visceral hump*, which lies within, and has the shape of, the shell. In a living snail, just beneath the shell, may be seen a round orifice which alternately shuts and opens. This is the *pulmonary orifice*, and leads into the *mantle cavity*, a cavity formed by a fold of the integument, as is the mantle of the Anodon. The *eyes* are borne upon a pair of long and retractile stalks. Below these are a second and smaller pair of *tentacles*. The *mouth* lies below the latter, while behind the tentacles is, on the right side, a pore, connected with an external groove, the *generative aperture.* Apart from the unilateral generative pore, that portion of the body which lies outside the shell is bilaterally symmetrical. There is no more evidence of segmentation in the snail than there is in the Anodon. The *shell* of the snail has a spiral cavity; it is formed by the coiling of a shelly tube, the common wall formed by the apposition of the coils being itself at first hollow. The term *columella* is applied to this. That the shell is univalve implies no marked distinction from the shell of Anodon. It is simply due to the continuous secretion of calcareous matter instead of its secretion in two plates, as in the Anodon. The mantle cavity is a spacious chamber corresponding, of course, to the spaces which lie beneath the mantle-flaps in *Anodonta*. It is, therefore, morphologically a part of the exterior. The name "lung" sometimes applied to this cavity is, therefore, so far misleading. Nevertheless, this chamber performs the function of a lung, as the animal has no gills such as are found in other Cephalous Mollusca. The walls of the mantle cavity are thin, and just beneath the integument is an abundant plexus of blood-vessels, whose blood is thus brought into near relations with the air contained in the "lung." This (the air) is renewed and expelled at intervals, as already mentioned. Into the mantle cavity open the anus and the renal gland.

When the snail is dissected the same absence of *cœlom* that characterizes *Anodonta* is to be remarked. As in that animal, the only remaining portion of the cœlom is the *pericardium*, which surrounds the heart. No other organs, however, lie within the pericardium, but the single renal organ opens into it by a reno-pericardial pore.

The *alimentary canal* is more complex than that of Anodon. The mouth leads into a cavity called the buccal mass, which has thick muscular walls, and whose floor is supported by cartilage. Upon this cartilage lies a structure characteristic of all the Cephalous Mollusca known as the *radula*. This is a stiff ribbon which is developed into a series of teeth, closely set and overlapping each other. The ribbon bearing these teeth is set in motion by muscles attached to the underlying cartilages, and the food is thus torn to shreds. From the

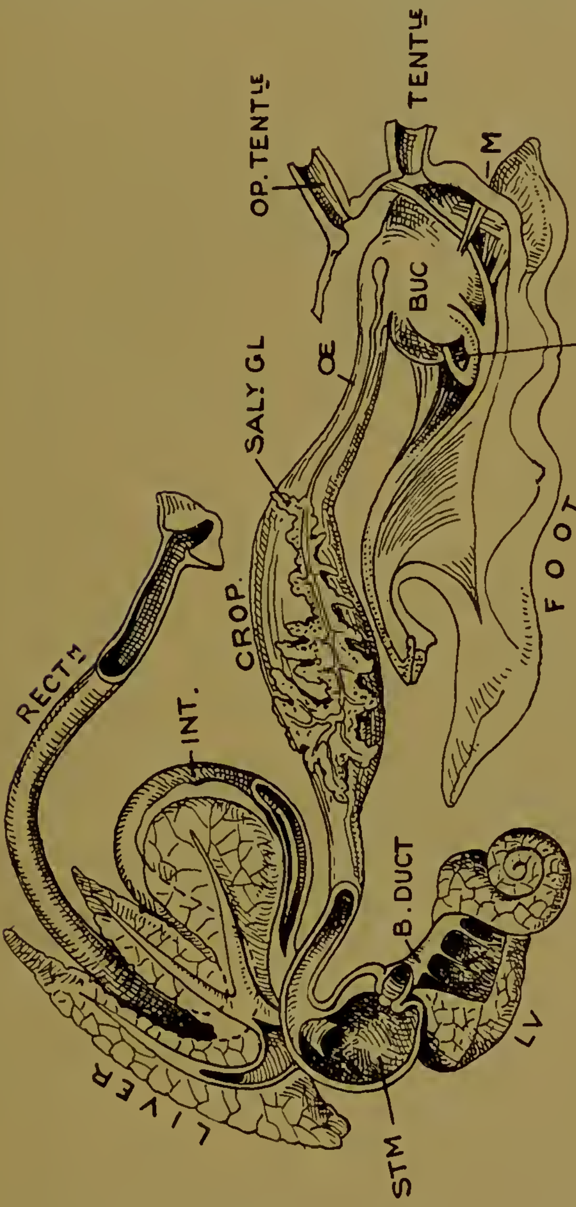

FIG. 31.—Alimentary canal of Snail. (After Howes.)

Œ, œsophagus; BUC, buccal mass; RAD, radula; M, mouth; OP. TENTLE, optic tentacle; LV, liver; STM, stomach; INT, intestine; SALY GL, salivary gland.

buccal mass leads a narrow œsophagus, which presently widens into a *crop;* it again narrows, to open into a rather globular *stomach*. From the stomach arises an *intestine* which, after two or three turns, becomes the straight rectum leading to the anal orifice. The alimentary canal of the snail is well supplied with glands. There are, first of all, the *salivary glands*, one on either side of the crop. From each a fine duct passes forwards, and opens into the buccal mass just at its junction with the œsophagus. The *liver* is a four-lobed brown mass, occupying a great portion of the visceral mass, lying within the visceral hump. Its ducts open into the stomach.

The *heart* has one auricle and ventricle. Into the auricle is poured the blood derived from the numerous vessels which ramify over the surface of the mantle. From the ventricle arises an artery, which subsequently divides and supplies the body generally. The *blood* is faintly blue when exposed to the atmosphere, the blue colour being due to a respiratory pigment (hæmocyanin), analogous in its oxygen-carrying powers to hæmoglobin, but of a different chemical composition. Its metallic basis is copper instead of iron. The blood contains colourless amœboid corpuscles. The *renal organ* is single; it corresponds to one of two organs of Bojanus of the fresh-water mussel. It opens, as already said, into the pericardium (= cœlom) on the one hand, and on to the exterior, within the mantle cavity, on the other.

The *nervous system* is constituted quite upon the plan of that of Anodon. The ganglia, however, are more crowded together. The cerebral ganglia lie above the œsophagus, and give off each of them a nerve which ends in a small buccal ganglion, lying upon the buccal mass, and innervating it. Connected with the cerebral ganglia by commissures passing round the œsophagus are the pedal ganglia. On the pedal ganglia lie the small auditory sacs; but although these lie upon the pedal ganglia, their supply-nerves come from the cerebral. Behind the pedal ganglia are the chlamydo-splanchnic, also connected by commissures with the cerebral.

As is generally the case with hermaphrodite animals (cf. the earthworm), the *organs of reproduction* are excessively complicated. The essential part of the generative system is the *hermaphrodite gland*, or *ovo-testis*, which produces both

FIG. 32.—Reproductive organs of Snail. (After Howes.)

AL.GL, albumen gland; HER.D, hermaphrodite duct; HERM.GL, hermaphrodite gland; SP, spermatheca; OV.D, oviduct; PR, prostate; FLA, flagellum appended to male duct; GEN.VS, genital vestibule; RET.MUS, retractor muscle.

spermatozoa and ova. This is connected by a duct with a large gland, the *albumen gland.* Some time after this the common duct divides into a *vas deferens* and an *oviduct.* To each separate duct a system of glands and diverticula is appended, which are illustrated in the figure (Fig. 32). The snail deposits its ova in the earth; the embryos have, as is usual with terrestrial animals (to which, however, there are plenty of exceptions, *e.g.* insects), no free larval stage.

CHAPTER IX.

THE FROG (RANA TEMPORARIA AND RANA ESCULENTA).

THIS country is inhabited by two species of **Frog**. One, *Rana temporaria*, is abundant everywhere—where, that is to say, suitable conditions are to be met with. The other frog, *Rana esculenta*, the so-called "edible frog" (but both, as a matter of fact, are eaten), is found in some of the eastern counties. There is, however, more than one reason for regarding this species as not truly indigenous to this country; it has been artificially introduced at more than one time.

FIG. 33.—The upper side of the head of the male *Rana esculenta*, showing the vocal sacs inflated.

R. esculenta may be distinguished from *R. temporaria* by the existence in the male of inflatable vocal sacs, by the absence of a characteristic dark patch of pigment behind the eye, and by the larger prehallux in the foot. It is, moreover, a larger species, and is more purely aquatic in habit than its smaller indigenous ally.

The frog varies considerably in colour, being in some cases darker and in others lighter. This variation of colour is dependent largely upon the animal's surroundings, and changes with any changes in the environment. Thus, if a frog be kept for some time in a white dish it will become paler in tint; if shaded, the hues will darken. This power of changing the colour is due to the contraction or relaxing of certain pigment-cells in the skin, and is a phenomenon which is common among the lower vertebrates. It is seen in other Amphibia, in many fishes, and in reptiles, the chameleon being the most familiar instance of the latter.

The body of the frog is moist, the skin secreting a fluid by means of certain glands imbedded therein. A too dry atmosphere is ultimately fatal to the animal.

The *body* is divisible into *head*, *trunk*, and *limbs*, to which regions of the skeleton (p. 85) correspond. There is no recognisable neck or tail. The large *mouth* is provided with teeth, which are limited to the upper jaw. Posteriorly there is but one aperture, the *cloacal*. On the head are the three organs of special sense; the *nostrils* anteriorly, the *eyes* following, and behind these, on either side, a tight drum-like membrane, the *tympanum*, which covers the tube leading to the ear. The sense organs, it will be seen, are arranged in a segmented fashion.

There are some other characters which can be noted without dissection. If the mouth be opened, two small orifices, the *internal nares*, are seen to communicate with the *external nares* (the nostrils). Considerably further back are the two *Eustachian tubes*, which communicate with the auditory meatus lying beneath the tympanum. The teeth have been already referred to. The *tongue*, which is bifid at the tip, and can be stretched to a fair length, is attached anteriorly in the mouth cavity. It is by the rapid extension of the tongue, and by the viscid fluid secreted from it and covering it, that the frog is enabled to capture its (generally insect) prey.

When the skin is removed preparatory to opening the body, it will be seen to be loosely attached to the underlying muscles. This is caused by the presence of large subcutaneous *lymph spaces*. When the thin layer of muscles in the abdominal region is cut through, a large cavity is exposed, in which lie nearly all the viscera. This is the body cavity, or *cœlom*. It extends through the abdominal and thoracic regions, but does not push its way into the head or the limbs. Thus the body of the frog is hollow, the walls consisting of the skin externally and of the skeleton and muscles next, which form together the body-wall. A more careful examination of the cœlom shows that in reality the various organs, which are exposed by opening it up, do not lie within it. The alimentary tract, which is the most conspicuous of these, is tied down to the dorsal side of the cavity by thin sheets of tissue, the *mesenteries.* These mesenteries are double, and embrace the alimentary canal, thus shutting it off from the cœlom. The same applies to the kidneys, heart, and other organs.

The only organs that can be said to really lie actually in the body cavity are the male and female gonads, the testes and ovaries. They are formed by a proliferation of the membrane which lines the cœlom. The mouths of the oviducts in the female frog, moreover, open actually into the cœlom, the lining membrane of which is continuous with their mouths. A special part of the cœlom is separated off from the rest, and forms the *pericardium*, enclosing the heart. Mention has been made of the subintegumental lymph spaces; these spaces are in communication with a system of vessels which ramify through the body, often accompanying the blood-vessels, and which open into the cœlom. This lymph system contains a colourless fluid, in which float colourless nucleated corpuscles, similar to those of the blood. Lying beneath the skin of the back, just in front of the cloacal aperture, and between the third and fourth vertebræ, are certain muscular contractile sacs, the *lymph hearts*, which pump the lymph into the veins in their neighbourhood; the cœlom thus, through the lymph system, is in communication with the vascular system.

The *alimentary canal* of the frog commences with the *mouth cavity* and ends posteriorly in the cloacal cavity. The mouth and teeth have been already referred to, and the latter will be more particularly described in the section dealing with the skeleton. The mouth cavity is followed by the *œsophagus*, which leads into the *stomach.* The stomach is a bent tube, wider at first, and gradually diminishing in calibre as it passes into the small intestine; the junction of the two is marked by a fold of the lining membrane. The *small intestine* is narrow and coiled.[1] The *large intestine* is wide and short, ending in

[1] The coiling of the intestine allows a large secretory and absorptive surface to be stowed away in a small space. This surface is

the *cloaca*. Into this terminal chamber opens, firstly a large bifid *bladder*, and just below it the ureters and (in the female) the oviducts.

Appended to the alimentary canal are two large glands. Of these the *liver* is much the largest, and is divided into two principal lobes, a right and a left. Attached to the lower surface of the liver is the usually bright green *gall-bladder*. From this a duct leads through the *pancreas*, in the substance of which it is joined by the ducts of the pancreas, and finally opens into the duodenum, as is called the first part of the small intestine.

The *circulatory system* of the frog consists of a central organ of impulsion, the *heart*, and of a system of tubes leading to and from the heart. Those conveying blood from the heart are termed *arteries*, and those returning blood to the heart are termed *veins*. Peripherally these are united by the minute *capillaries*, which permeate all the organs of the body. The vascular system is, as has already been stated, in communication with the cœlom through the lymphatic vessels. It contains, however, a different fluid. Besides the "*white*" *corpuscles* which are common to it and to the lymphatic system and cœlom, it has large, red, oval, nucleated discs, the *red corpuscles*. The red colouring matter of these is due to a substance called hæmoglobin, the importance of which will be considered in connection with respiration. The body of the frog is thus permeated by a second system of cavities distinct from the cœlom.

The *heart* is a stout muscular organ enclosed in a special compartment of the cœlom, the *pericardium*. Its cavity is divided into several chambers, which are in communication with each other. Behind the heart is the *sinus venosus*, into which the veins bringing back blood from the body generally open. This leads into the *right auricle*, which is separated from the *left auricle* by a septum. Into the left auricle open the pulmonary veins. Both auricles lead into the single *ventricle* by a common aperture, which, however, is divided into two openings.

further increased, without additional room for storage being required, by villi and folds upon its inner surface. The typhlosole of *Lumbricus* and of Anodon is a similar response to a similar need.

The walls of the ventricle are thick and spongy; its cavity is in communication with the *truncus arteriosus*, from which again arise the arteries. The truncus arteriosus is divisible into two regions. That nearest the heart is known as the *pylangium*; it is guarded by three semilunar-shaped valvules at its orifice into the ventricle, the effect of which is to prevent the reflux of blood into the ventricle when the former contracts. Along the rest of the pylangium is a free fold attached along one wall, which is believed to represent a series of smaller valves, such as occur in the heart of the lower fishes, fused together. At the end of this, above, three semilunar valves mark off from the pylangium the distal *synangium*. From this immediately spring the two (right and left) arterial trunks. These latter, although apparently single trunks, are really divided internally into three vessels on each side.

The arterial system of the frog is illustrated in the accompanying diagram (Fig. 34). The anterior of the three vessels arising from the synangium is the *carotid*; it divides into two branches, the external and internal carotid. At the origin of the former is a little thickened portion of the arterial trunk which is known as the *carotid gland*. The term "gland," however, is quite inaccurate; it is simply a network upon the vessel, the trunk of which divides into a skein of vessels to reunite again. The middle of the three trunks is the *systemic aorta*. It passes round the gullet, and joins its fellow of the opposite side beneath the œsophagus. At the points of junction a stout branch is given off, the cœliac, which supplies the viscera of the abdomen. From each half of the aorta before they join a branch arises which again divides into the *brachial* (supplying the fore limb) and a *vertebral* artery. The third of the three arches is the *pulmo-cutaneous*; it divides into two trunks, one going to the lungs, the other to the skin.

The blood is returned to the heart by a system of veins, which is rather more complicated than the arterial system. It is more complicated because there are two subsidiary circulations introduced along the course of the vessels. The blood from the head and from the fore limbs is returned to the right auricle by a series of trunks which are shown in the accompanying

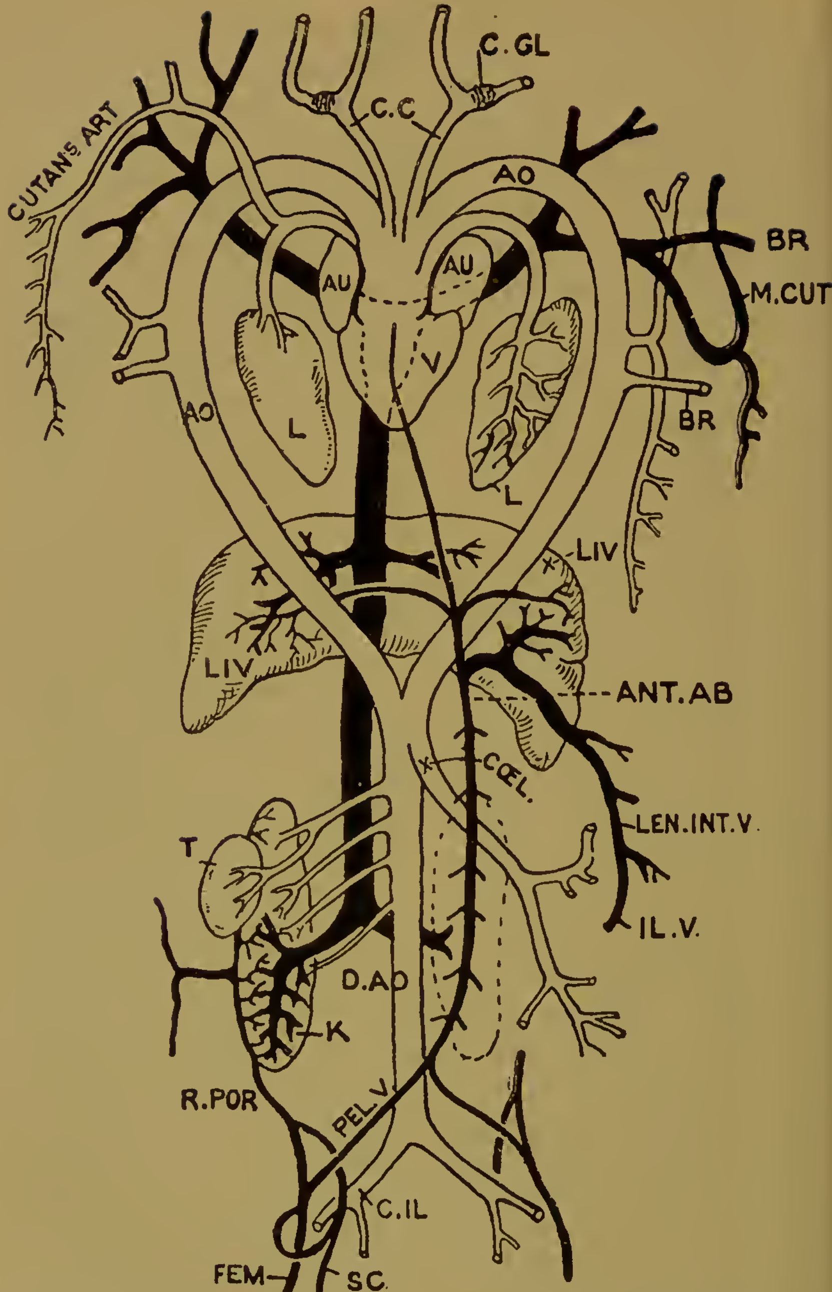

FIG. 34.—Diagram of vascular system of Rana. (Compound figure, after Howes.)

The venous system is black, the arterial white. (N.B. the arterial vessels are really deep of the veins, not superficial.) AU, auricles; V, ventricle; AO, aortic arch; C.C, carotids; C.GL, carotid gland; BR, brachial artery; BR (black), brachial vein; M.CUT, cutaneous vein; ANT.AB, anterior abdominal; L, lung; LIV, liver; CŒL., cœliac; LEN.INT.V, IL.V, portal vein; T, testis; K, renal organ; R.POR, renal portal; D.AO, dorsal aorta; FEM, femoral vein; PEL.V, pelvic vein; SC, sciatic vein.

diagram. The names of the several vessels and the points at which they unite are there indicated, and an inspection will serve instead of a description. In the same simple fashion the blood is returned to the left auricle from the lungs. It should be noted, however, that while generally the veins correspond to the arteries, this is not the case with the *cutaneous vein.* This vein joins the *jugular* system, while the cutaneous artery is derived from the pulmonary artery.

The blood from the renal organs and from the liver is also returned directly to the heart by way of the *posterior vena cava.*

From the rest of the body the blood is not returned directly to the heart. The *femoral vein* bifurcates in the pelvic region into two vessels, of which one runs to the kidney, and there breaks up into a series of capillaries; the other branch joins its fellow of the opposite side to form the *anterior abdominal vein*, a vein running just below the muscles of the abdomen, which can be seen through those muscles before they are cut. This anterior abdominal vein divides anteriorly into two branches, one for each of the two lobes of the liver, in the interior of which it breaks up into a capillary network. A minute twig, however, has been described as going directly to the heart. The *renal portal vein*, as that branch of the femoral which goes to the kidney has been termed, is reinforced by the *sciatic vein.* Besides this *renal portal system*, as the vessels which pour their blood into the kidneys are collectively termed, there is an *hepatic portal system.* The veins from the alimentary canal unite to form a largish trunk, the *portal vein;* this enters the liver, and there breaks up into a capillary network. Thus all the blood from the hind limbs passes on its way to the heart either through the kidneys or through the liver, with the exception of a small quantity which reaches the heart directly by way of the small branch of the anterior abdominal already referred to.

The *respiratory organs* of the frog consist of a pair of lungs; these open by a short tube, which is strengthened by certain cartilages, into the pharynx. Each lung is a sac with thin walls, which are abundantly supplied with blood capillaries, the branches of the pulmonary arteries. When the frog breathes it fills the mouth with air; the mouth is then closed and the external nares, while the muscles forming the floor of the mouth force the contained air into the lungs. Expiration is effected by the abdominal muscles, which press upon the viscera, and so upon the lungs, expelling the air. It appears, however, that the frog can also breathe by means of the skin, which is, it will be remembered, supplied with blood by the cutaneous artery, a branch of the pulmonary. Respiration is essentially an exchange of gases between the blood and the air in the lungs. The hæmoglobin, which tinges the red blood corpuscles, has the power of absorbing and entering into loose combination with the oxygen drawn into the lungs; this oxygen is then given up with equal ease to the tissues through which the blood passes after it has been through the lungs. The carbonic acid which is there absorbed is given up to the outside when the blood returns to the lungs.

The *nervous system* consists of the central nervous system, the *brain* and *spinal cord*, from which arise *nerves* which constitute the peripheral nervous system. These nerves end either in the muscles or in sense organs; they are either motor in function, or sensory.

The central nervous system, unlike that of any of the invertebrate types, is entirely dorsal in position. It runs in a canal formed in front by the skull, and behind by the vertebral column. Furthermore, the central nervous system is really a hollow tube, though the thickness of its walls far exceeds the diameter of the lumen, save in certain regions of the brain. By these two important facts the central nervous system of all vertebrated animals can be distinguished from the central nervous systems of other animals.

The *brain* is divisible into several regions; in front there is an unpaired region from which arises the two *olfactory nerves*, going to the nose; this is the *olfactory lobe*. Behind this are the paired *cerebral hemispheres;* then follows a region, which is depressed below the level of these, and is known as the *thalamencephalon*. From the upper surface of the anterior part of the thalamencephalon arises a short stalked body, the *pineal body;* this structure is the rudiment of an unpaired eye, fully, and possibly even functionally, developed as an eye in certain other vertebrates. Behind the thalamencephalon come the two *optic lobes*, the *corpora bigemina*, as they are sometimes termed. Then a narrow band of brain tissue stretches across to form the *cerebellum*, rudimentary in the frog, but of great importance in the higher vertebrates. Behind this, again, is the *medulla oblongata*, which gradually narrows into the spinal cord. Ten pairs of nerves arise from the brain, which are as follows: (1) *olfactory*, supplying nose; (2) *optic*, supplying eyes; (3) *motores oculorum*, supplying most of the muscles of the eye; (4) *pathetici*, supplying the superior oblique muscles of the eye; (5) *trigeminus*, with three branches running to the skin of the front part of the head and the lower jaw; (6) *abducentes*, supplying the external rectus and retractor bulbi muscles of the eye; (7) the *faciales*, supplying the roof and the floor of the mouth; (8) the *auditory* nerves, going to the ear; (9) the *glossopharyngei*, to the root of the tongue; (10) the *vagi*, supplying the dorsal integument of the head and trunk, and the heart, lungs, and stomach.

The *spinal cord* gives off ten pairs of nerves; the first is the *hypoglossal*, which supplies certain muscles at the back of the head; the next two nerves unite a short way from their origin, and form a trunk supplying the fore limb. This union between the two nerves is known as the *brachial plexus*. The seventh to the tenth spinal nerves form another plexus, which is concerned with the nerve-supply of the hind limb.

The *sympathetic system* consists of a chain of ganglia on either side of the aorta. The *renal organs* of the frog consist of a pair of kidneys, which really do not deserve the name of kidneys, as they correspond to the mesonephros of the embryo fowl (see p. 140). They are reddish bodies, and on the surface of each is a yellowish band, the *adrenal body*. The duct of each mesonephros opens into the *cloaca*, that of the male being provided with a little glandular cæcum known as the *vesicula seminalis*. From the cloaca in both sexes arises a bilobed *bladder*. In the male frog there are a pair of egg-shaped *testes*; the ducts from these pass through the mesonephros, and reach the exterior by the *mesonephric ducts* (the "ureters"). At the anterior end of the testes are a pair of lobed bodies, the *fat bodies*. The *ovary* of the female is much more extensive than the testis, but it has the same fat body attached to its anterior end. The eggs are shed freely into the cœlom, and are caught up by the open mouths of the *oviduct;* the oviducts are much-coiled tubes which open into the cloaca.

The Life-History of the Frog.

The male frog at the breeding season develops a thick glandular pad upon the index fingers. This assists the male in clasping the female firmly, which is done during the period of oviposition, the milt being shed upon the ova as they are extruded. The eggs are enveloped in a thick transparent coat derived from the walls of the oviduct, which contains mucin, and swells up when brought into contact with water. The actual eggs themselves are smallish round bodies, black at one pole and white at the other.

The **Tadpole** is hatched out at a very early period of its development. It is the rule of the frog tribe for tadpoles to be produced; but the rule is not without exceptions. In a few cases there is no tadpole stage at all, the young frogs making their way out of the egg. When the tadpole is hatched it has no mouth, and is therefore still dependent upon the yet unabsorbed yolk for its nutrition. It has a horse-shoe-shaped sucker below the future position of the mouth, by means of which it moors itself to leaves or stones. It has pairs of external gills, which are outgrowths of the skin, and possibly represent the simple cutaneous gills of some invertebrate ancestor. In various marine worms, for example, there are gills of this character. Later, the mouth becomes apparent, and its interior is furnished with a series of horny teeth, the precise arrangement of which has been shown to be characteristic for the tadpoles of different kinds of frogs. The alimentary canal grows long, and is coiled in a peculiar fashion, somewhat like the spring of a watch; this form of the alimentary tract is associated, in the common frog, with a purely vegetable diet; but there is no necessary association of the kind, for the tadpoles of the Cape clawed frog (*Xenopus lævis*) have an equally watch-spring-like intestine, but feed—chiefly, at any rate—upon small crustaceans. The external gills presently shrivel up, and are replaced functionally by the internal gills. At the sides of the pharynx a series of slits appear, which put the interior of the pharynx into communication with the

FIG. 35.—The young Tadpole of the common Frog (*Rana temporaria*), enlarged, showing the external gills.

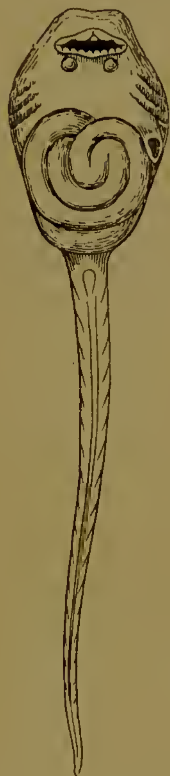

FIG. 36.—The under side of the Tadpole of the Frog, showing the coiled digestive tube, the suckers (not joined), the internal gills, and the respiratory aperture, enlarged.

medium in which the animal lives; these *gill-slits*, or visceral clefts, become fringed with vascular tags, which are the actual respiratory organs. The intervals between the successive clefts are occupied by cartilaginous bars, the *gill-arches*, or visceral arches, the function of which is to keep open the clefts, and so allow of a free flow of oxygen containing water over the gills. When the gill-clefts and the associated gills appear, a fold of skin, the *operculum*, arises from the side of the head, and grows over the gills, remaining open only at one point. This is on the left side of the body, and its margin projects in a spout-like fashion. It will be observed that in this stage of its existence the young frog is practically a fish. If it grew no further, and were to develop sexual organs, it would have to be classified with the fishes. It has the gills of the fish, its circulatory organs are constituted upon a similar plan, and the body is fringed dorsally and ventrally with a continuous fin-fold as in many fishes. But it has no lateral fins corresponding to the paired fins of the higher fishes. These appear later in the form of the limbs of the adult frog. The lungs also soon appear, the tail gets less, respiration is effected entirely by the lungs, and the tadpole leaves the water a frog.

CHAPTER X.

SKELETAL AND INTEGUMENTARY STRUCTURES IN VERTEBRATES.

THE frog belongs to the group of **Vertebrata** whose characters are given below. The Vertebrata contrast with any Invertebrate type by the possession of an elaborate internal skeleton, which is in the lowest forms entirely, or nearly entirely, cartilaginous, and ossified in the higher types. The characters derived from the study of the skeleton are exceedingly useful in classifying vertebrates. In the following pages, therefore, an account will be given of the skeleton in three types: in the frog, the fowl, and the rabbit.

The Vertebrata can be also, to a large extent, differentiated by certain external features. The Mammalia, for example, are the only vertebrates which possess hair; feathers are unknown outside the class of Birds, while the scales of Serpents and Lizards are totally different from the similarly named structures of Fishes. As the teeth are really, as will be shown later, epidermic structures, they will be included in a survey of the principal external (integumental) characters of the vertebrates.

VERTEBRAL COLUMN.

The vertebral column of the **Frog** consists of a number of separate vertebræ—very few as compared with the other vertebrate types. The frog has altogether only ten vertebræ, exclusive of the long urostyle, which is never broken up into separate vertebræ, but appears to be the equivalent of three.

The first vertebra is called the *atlas*, and it is followed by the second, or *axis*. After this come seven vertebræ with well-developed transverse processes, and an eighth vertebra with particularly strong transverse processes, which support the pelvic bones. The anterior set may be termed "dorsals," and the vertebra which supports the pelvis "sacral." In order to satisfactorily compare the vertebræ of the frog with those of the other vertebrates, it will be necessary to enter into the development of the vertebral column.

Unlike the skull, the entire vertebral column is formed out of cartilage. The cartilages, when they first appear, appear round the notochord, the development of which structure, the precursor of the vertebral column, is dealt with on another page. There are typically four pairs of cartilaginous elements arranged in sets, of which, however, some may be suppressed. They have been called by the following names: basidorsalia, basiventralia, interdorsalia, interventralia. In the common frog the interventralia are suppressed, and the entire vertebra is formed by the coalesced basidorsalia, interdorsalia, and basiventralia. In the bird's vertebral column the separate vertebræ are formed of other elements. The centrum of the vertebra is formed of the interventralia, the basidorsalia form part of the neural arch, and, finally, the basiventralia are converted into the intercentra, where these latter exist. The same statements hold for the vertebral column of the mammal. In both these latter groups the atlas is peculiar, in that its centrum remains free from the interventralia, and becomes attached to the centrum or the following vertebra, the axis. It is clear, therefore, that a vertebra of the frog does not exactly correspond to a vertebra of either a bird or a mammal. Moreover, apart from their being formed out of partly different elements, and therefore not exactly corresponding, there is not even a rough correspondence between the atlas of the frog, on the one hand, and of the bird and mammal on the other. It has been pointed out that the frog has only ten pairs of cranial nerves; the fowl and the mammal have twelve. This naturally leads to the view, supported by other data, that the skull of the higher vertebrates is more extensive than that of the frog. There are, in fact, rudiments of, apparently, at least two vertebræ co-ossified with the occipital bone in the higher vertebrate, which must, therefore, be looked upon as the equivalents of the two first vertebræ of the frog, whose atlas, in consequence, is not to be strictly compared with the atlas of either bird or mammal.

The vertebral chain of the **Fowl** has been found to consist of 46 or 47 vertebræ. The number appears to be rather less than this; but it will be noted that the posterior end of the column is formed of a ploughshare-shaped bone, the pygostyle or urostyle, which is really a compound bone made up of separate elements. These separate vertebræ can be divided into four series. There are, first of all, the *cervical vertebræ*, sixteen in number. The term "cervical" is commonly applied to those in front of the first vertebra, which bears a complete rib articulating with the sternum; but really there is no hard-and-fast line of division, since the last two of the cervical series bear free ribs, which, although they do not reach the sternum, increase progressively in length. The cervical vertebræ lying in front of these latter appear to have no ribs; but they really have short ribs, which are firmly coalesced with the vertebræ, so as to surround a canal, through which an artery passes. Each cervical vertebra, like the remaining vertebræ, except those at the tail end of the body, consists of a *centrum*, which articulates in front and behind with the preceding and succeeding vertebra by a surface which is concave in the middle, and more convex peripherally; it has been compared to the outline of a saddle, and the centra of birds have been described as having saddle-shaped articulating surfaces. This method of articulation ensures considerable mobility, and the neck is long. Rising from the centrum is an arch of bone, the *neural arch*, which projects at the top in a varying degree to form the *neural spine;* this surrounds the large neural canal, in which lies the spinal cord. The ribs are attached by two heads: by a *capitulum* to a smooth surface upon the centrum, and by a *tuberculum* to an outgrowth of the neural arch, the *transverse process*. In addition to these various processes and regions of the vertebra, there is commonly a ventral median process, the *hypapophysis*, which is simply a downward growth of the centrum, and not to be confounded with an apparently similar downward process of the caudals.

The last cervical vertebra is fused with the three following vertebræ; this gives great solidity to this region of the back, which has to support the sternum. The last dorsal vertebra (we restrict the term *dorsal* to those vertebræ which carry complete ribs) is free, and not ankylosed with the preceding. After this follows a large series of vertebræ which are closely attached to each other and to the pelvis, which they support. Here again the fusion of the vertebræ gives great stability to the pelvis and a firm *point d'appui* for the articulation of the legs. These fused vertebræ are sometimes termed sacral; but it is better to reserve the term "sacral" for the two vertebræ which in the embryo chick articulate with the ilia; those lying in front of this point may be called *lumbar*, and those lying behind *caudal*. Behind these last there are a number of free caudal vertebræ, and the column terminates in the *ploughshare bone* (pygostyle), which is the product of a number (six) of fused vertebræ, which thus form a strong basis for the attachment of the strong quills of the tail, the rectrices. The free caudal vertebræ have slight downward processes, arising from the centra; these structures are really, and actually, in some birds, separate bonelets, the *intercentra*, which are independent of the centra to begin with, and only become fused with them later.

The first cervical vertebra is known as the *atlas*, the second as the *axis*, or *epistropheus*. The latter is furnished with a peg-like forward outgrowth of the centrum, which fits into a notch of the apparent centrum of the atlas. We say "apparent," since the peg—the *odontoid process*, as it is usually called—is really the detached centrum of the atlas.

The vertebral column of the **Rabbit** can be also divided into regions. First of all there is the cervical, with but seven vertebræ (a number which is curiously constant among the Mammalia, there being only three or four exceptions); then follows the dorsal series, then the lumbar, the sacral, and, finally, the caudal. The rabbit has twelve dorsal, seven lumbar, four sacral, and fifteen caudal vertebræ.

There are three salient points of structure which distinguish the vertebral column of the rabbit from that of the bird. In the first place, the centrum is ossified in three pieces—a central one and two epiphyses (one at each end); secondly, the surfaces of articulation are flat instead of saddle-shaped; thirdly, the first vertebra (the *atlas*) articulates with the skull by two facets, instead of only one, as in the bird. The *axis*, or epistropheus, is like that of the bird in having a peg-like odontoid process—really the centrum of the atlas. The dorsal vertebræ have very long spinous processes, associated with strong muscles to hold and move the heavy head. The lumbar vertebræ have very long lateral processes known as *metapophyses*. The rabbit has twelve, sometimes thirteen, pairs of ribs; of these the eight anterior are borne by two heads, the capitulum and the tuberculum. The former is articulated with a small semi-lunar facet on the junction of each successive pair of centra; the seventh cervical vertebra bears the half of the first of these facets. The last four vertebræ lack the tubercular head upon the transverse processes; they have only the capitular head. Seven ribs reach the sternum.

Skull.

The skull was at one time regarded as a single structure, formed of a number of coalesced and modified vertebræ. The anatomical knowledge and genius of Goethe and Owen succeeded in impressing this view of its nature upon comparative anatomists, until the theory was finally overthrown by Huxley in 1858. The skull is now known to be composed of a series of elements which have primarily no connection with each other. It is built up of—

1. The originally cartilaginous and afterwards, in all animals above the elasmobranch fishes, ossified *brain-case* or *cranium* proper.

2. Of the cartilaginous (or ossified) *capsules of the* three *organs of special sense*—the auditory, olfactory, and optic.

3. Of portions of, at least, the first two of the *visceral*

arches—structures which were all originally bars of cartilage for the strengthening and support of the branchiæ.

4. Of the *labial cartilages.*

5. Of certain *membrane bones* ossified in the skin generally, or limited to the head region.

To understand how these various and quite different tracts of cartilage or bone combine to form the solid whole that we term the skull, it will be convenient to briefly trace the development.

1. The *brain-case* in its early condition consists of a pair of stiff rods situated anteriorly, and known as the *trabeculæ cranii;* these lie in front of the notochord, and become fused with each other anteriorly between the nasal sacs, again diverging in front of the area of fusion to form a plate on each side, which dips into and supports the upper lip. As the embryo grows the trabeculæ grow backwards and come into contact with a pair of rods lying on either side of the notochord, the *parachordal cartilages.*

The state of affairs arrived at is illustrated in Fig. 37. All these cartilages constitute the brain-case, or cranium, and the brain lies upon the platform thus formed. Ultimately the walls of the brain-case are formed by the growing up of the sides of these cartilages, which come to more or less enclose the brain, fontanelles being left dorsally. In the frog it so happens that the trabeculæ cranii are formed before the para-chorials, but this is not the rule among the Vertebrata. The separate bones, which are finally formed by the ossification of the cranium, will be mentioned later. We may next consider—

2. The *capsules of the sense organs.* Of these, the *auditory capsules* alone have an important share in the building up of the skull. Quite independent of the parachordal cartilages, but abutting upon them, is a roundish mass of cartilage on either side, which contains the auditory organ. This soon becomes continuous with the side walls of the skull, and helps in the formation of its side, and even its dorsal walls. The *capsule of the eye* has practically no share in the building up of the skull. The sclerotic coat of the eye is cartilaginous in the lower vertebrates, and in birds becomes ossified into a ring of bone-

lets; but in no animal does the cartilage, or bone, form an integral part of the skull wall. It remains permanently in a condition which is primitive and transitory in the case of the auditory capsule. Finally, there is the *capsule of the olfactory organ.* This is also relatively unimportant, but does become an actual, though a small, portion of the wall of the adult skull. The upper nasal wall of the frog's skull appears to be partly or entirely formed of the capsule. And in other vertebrates it

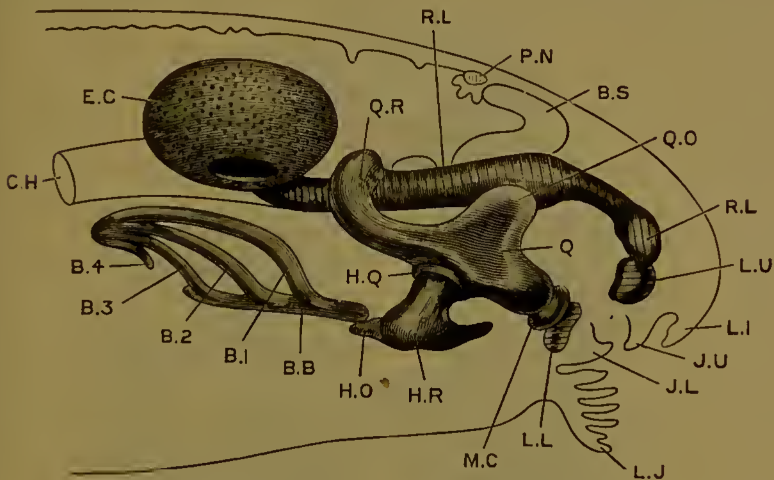

FIG. 37.—Skull of Tadpole. Lateral view. (After Marshall.)

The different elements which enter into the formation of the skull are indicated by different shading. *Cranium*, marked with vertical lines; *capsule of sense organ*, dotted; *visceral arches*, shaded with fine lines; *labial cartilages*, marked with horizontal lines. C.H, notochord; E.C, auditory capsule; Q. quadrate; Q.O, palato pterygoid; Q.R, articulation of quadrate; H.R, ceratohyal; H.Q, its articulation with quadrate; H.O, urohyal; R.L, trabeculæ cranii; L.L, L.U, labials; M.C, Meckel's cartilage; JU, JL, jaws; LI, LJ, lips; BS, cerebral hemisphere; PN, fineal body.

enters into the formation of the cartilages which protect the nasal organ.

3. In the tadpole, which breathes by means of gills, the side of the throat is pierced by four gill-clefts, which are slits putting into communication the interior of the pharynx with the exterior. The walls of these gill-clefts (for a further description of which see p. 135) are strengthened by the appearance of *cartilaginous bars.* Of these, the first and part of the second form an integral part of the adult skull. The first arch is termed the *mandibular;* it sends forward a process which becomes fused with the skull

wall in front in the trabecular region; posteriorly it also acquires an attachment to the auditory region of the skull wall. Below the process the arch becomes segmented off into a lower piece, which bears at its end the lower labial cartilage already spoken of. The lower piece is known as *Meckel's cartilage*, the upper piece as the *palato-pterygoid bar*, the actual area of attachment to the skull wall behind being the *quadrate cartilage*. The second arch will be dealt with later.

4. The *labial cartilages* are of some importance in the lower

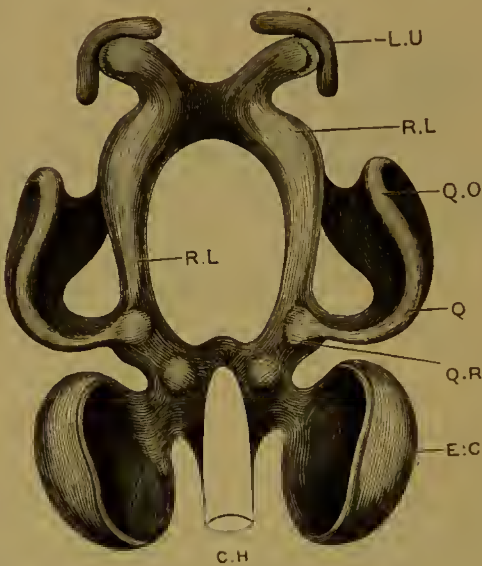

FIG. 38.—Skull of Tadpole. Dorsal view. (After Marshall.)
The parachordal cartilages are seen ensheathing the notochord. Lettering as in Fig. 37.

vertebrates, but diminish greatly—even to disappearance—in the higher forms. They have been looked upon as the vestiges of a cephalic skeleton which preceded the true skull. In the tadpole's skull there are a pair of upper and of lower labial cartilages. The former enter into the formation of the cartilaginous covering of the nasal organs in the adult.

5. Finally, there are a set of *membrane bones* in all vertebrates above the cartilaginous fishes, which ossify quite independently of the rest of the skull, and come to be closely applied to the upper, lower, and lateral surfaces of its cartilaginous walls.

These are relatively late appearances, and are greatly different in number in the several types of the Vertebrata, whose skulls we have to consider.

Up to this point there is a great similarity in all skulls. There is no wide divergence from this plan of structure and development, though, of course, plenty of slight differences in various details. The constitution of the adult skulls of frog,

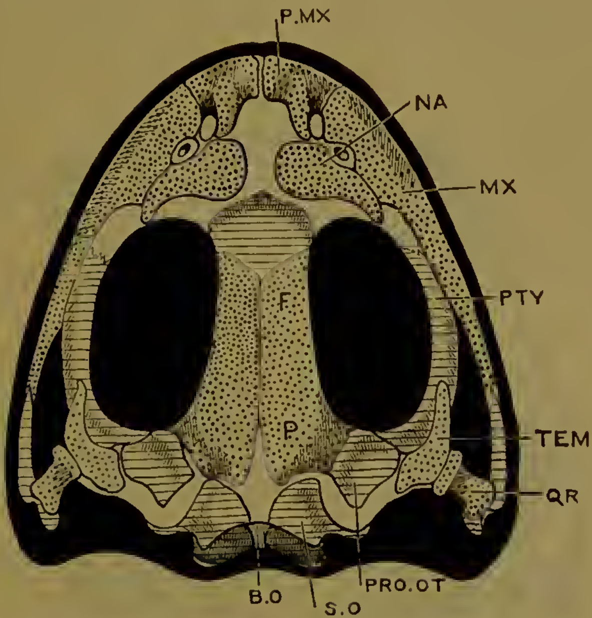

FIG. 39.—Skull of Frog. Dorsal aspect. (After W. K. Parker.)
The membrane bones are dotted; the cartilage bones transversely shaded; the cartilage is left white. This applies also to Figs. 40 and 41. B.O, basi-occipital region; S.O, exoccipital bones; PRO.OT, pro-otic; PTY, pterygoid; P, F, parieto frontal; NA, nasal; P.MX, premaxilla; MX, maxilla; TEM, squamosal; QR, overlies position of quadrate cartilage, and in front is quadrato-jugal (shaded).

fowl, and rabbit differ principally in the modifications of the visceral arches, in the number of the ossifications in the primordial cartilage, and in the membrane bones surrounding the skull.

As the **Frog's** *skull* is on the lowest level, we will commence with that. The absolute independence of the membrane bones from the underlying, partly cartilaginous and partly ossified, cranium is well seen by reason of the fact that they can without much difficulty be stripped off. Roofing the skull above are a pair of long bones, closely applied to each other in the middle line; these are the *fronto-parietals.* In front of these are the two *nasals* partly concealing the olfactory orifice, and in front of these, again, the small *premaxillæ.* On each side of the skull, in the auditory region, is a hammer-shaped *squamosal.* On the under surface of the skull the most conspicuous of the membrane bones is the large and dagger-shaped *parasphenoid*, of which

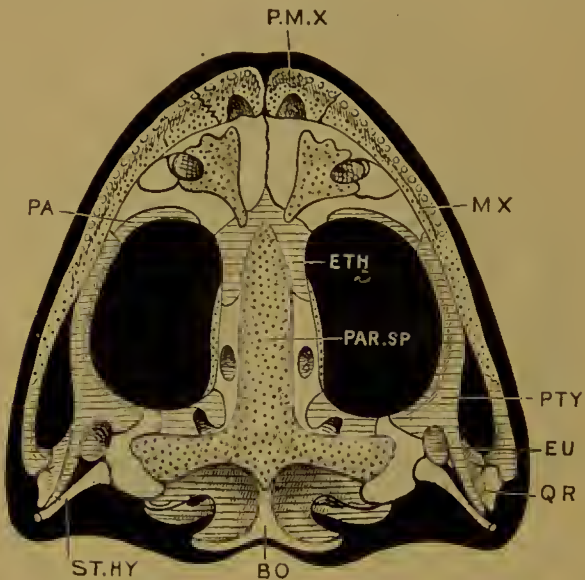

FIG. 40.—Skull of Frog. Ventral aspect. (After W. K. Parker.)
PA, palatine; ETH, sphenethmoid; PAR.SP, parasphenoid; EU, Eustachian tube; QR, quadrate; ST.HY, stylohyal. Behind PMX are vomers (dotted), in front of which are internal nares. Other letters as in Fig. 39.

the "blade" underlies the greater part of the base of the skull. In front of it, and bearing much the same relation to the internal nares as the nasal do to the external nares, are the small *vomers;* to the side the *maxillæ.* Laterally there is a splint of bone forming the outer arcade of the skull, the *quadrato-jugal.* The skull, thus stripped of its membrane bones, is seen to be chiefly cartilaginous, but with some ossifications.

These cartilage bones are not so numerous as the membrane bones.

On either side of the *foramen magnum*, through which the brain becomes continuous with the spinal cord, is a bony mass which also bears the *occipital condyles* for articulation with the vertebral column. These paired bones are the *exoccipitals*.[1] Continuous with each of these above, so as to appear to form but one bone, is an ossification in the auditory cartilage, the *pro-otic*. Beneath the anterior pointed end of the paraphenoid is a complete ring of bone, the *ethmoid*. On each side is a

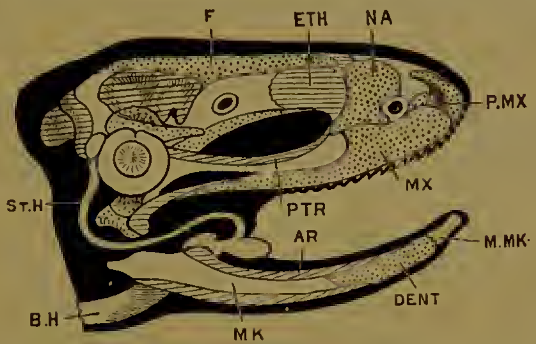

FIG. 41. – Skull of Frog. Lateral view. (After W. K. Parker.) BH, basihyal; MK, Mechel's cartilage; AR, articular; DENT, dentary; M.MK, mentomechelian; PTR, pterygoid. Other letters as in Figs. 39, 40.

Y-shaped bone running forwards, the *pterygoid*. This is hidden for a short space anteriorly by the tooth-bearing *maxillæ*, which latter abut in front upon the premaxillæ. The pterygoids are connected in front with the *palatines*, which lie transversely to the longitudinal axis of the skull. Finally, there is some ossification of the *quadrate*, which articulates with the lower jaw. The bones, cartilage, and membrane, which have just been enumerated, belong to the skull proper and to the sense capsules and the upper half of the first visceral arch, the palatopterygoid arcade. There is left a small bone, the *columella auris*, lying within the ear cavity and representing the top end of the second visceral arch; the lower jaw, which

[1] The existence of only a pair of ossifications in the occipital ring is not a character of frogs in general, but only of certain frogs. In others there are the four ossifications referred to above.

consists of a rod of cartilage, ossified near to its articulation into the *articulare*, and at its junction with the corresponding half, the *Mentomeckelian*: along the shaft it is covered by membrane bone, *dentary*; besides these, there is the *hyoid apparatus.* Two long processes, one on either side, connect the plate-like hyoid with the skull wall. Posteriorly a pair of ossified rods, the *thyrohyals*, represent one of the branchial arches proper.

It may assist the remembering of this complicated series of bones if they be arranged in accordance with the elements of the skull to which they severally belong, the membrane bones (distinguished by italics) being placed in their proper relations to the rest—

Cartilage Bones.	Membrane Bones.
BRAIN-CASE.	
Exoccipitals.	*Parasphenoid.*
Sphen-ethmoid.	*Frontoparietals.*
	Maxillæ.
	Premaxillæ.
CAPSULES OF SENSE ORGANS.	
Pro-otic.	*Squamosal.*
	Nasals.
	Vomers.
FIRST VISCERAL ARCH	
Quadrate.[1]	
Quadrato-jugal.[2]	
Pterygoid.[3]	
Palatine.[3]	
Articulare.	
Mento-meckelian.	*Dentary.*
SECOND VISCERAL ARCH.	
Columella.	
FOURTH VISCERAL ARCH.	
Thyrohyal.	

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[1] The degree in which the quadrate is ossified among frogs varies much.

[2] This is marked as a cartilage bone in my figures. More probably it is a membrane bone; but see following footnote.

[3] These are marked in the figures as cartilage bones. So they have been said to be. But perhaps the prevailing opinion is in favour of regarding them as membrane bones grafted on a cartilaginous substratum. I am unwilling, however, to attempt to decide between Prof. Parker (who colours these bones yellow, by which he means *cartilage* bones) and others. The fact is, it is not always easy to draw a hard-and-fast line between endosteal and ectosteal ossifications.

The *skull of a* **Fowl** contrasts greatly with that of the frog, but it is formed out of precisely the same elements, save that the labial cartilages are no longer represented. The most obvious difference in the skull of a full-grown bird is its complete ossification; it is only here and there that extremely small portions of the original cartilage are left. From this it follows that it is no longer possible to strip off the adherent membrane bones; they are firmly welded to the other bones, and, indeed, in the old skull the boundaries of the bones which form the brain-case are no longer to be detected.

In the bird's skull, not only is the primordial cartilaginous cranium much more completely converted into bone than in the frog, but the number of elements is greater.

The hinder region of the skull (see Fig. 42) is a ring of bone surrounding the foramen magnum, and is made up of four originally separate bones—the *basi-occipital* (Fig. 42, *b.o*), the *supra-occipital* (*s.o*), and two *ex-occipitals* (*eo*). The condyle, by means of which the skull articulates with the backbone, is single, and not double, as in the frog, and it is formed entirely out of the basi-occipital. The cartilaginous base of the skull in front of the basi-occipital is ossified to form three bones, one in front of the other, which are at first distinct; these are the *basi-sphenoid*, *pre-sphenoid*, and the *mesethmoid* (*eth*). The walls of the skull above these bones are formed by the *ali-sphenoids* and the *orbito-sphenoids* (*os*).

The auditory cartilage is ossified to form three bones, the *pro-otic*, the *epi-otic*, and the *opisthotic*.

The membrane bones, however, are hardly more numerous than in the frog. Covering the skull above, and lying in front of the supra-occipital, are the large *parietals* (*p*), in front of which, but separate from them, are the *frontals* (*f*). At the side of the frontals are the *lacrymals* (*l*), which are, as a rule, not co-ossified with the skull, but are easily detachable. The wide apertures of the nostrils are bordered behind by the bifid *nasal* (*n*) bones, below by the *maxillæ* (*m.x*), and in front by the long nasal processes of the *premaxillæ* (*px*).

On the under surface of the skull, another set of membrane bones are to be seen. Forming the base of the skull just in front of the basi-occipital, are the large bones which are usually called *basi-temporals.* They appear, however, to correspond to the "handle" of the dagger-like parasphenoid of the frog. Articulating with the quadrate is a narrow bone on each side, which converges towards its fellow, and is attached to a somewhat broader bone which runs forward in a straight line; these two bones are the *pterygoid* (*pg*) (posteriorly),[1] and the *palatine* (*pa*) (anteriorly). Between the palatines is a single compressed bone which is partly bifid posteriorly. This bone is the *vomer* (*v*). Its anterior end passes between two inward growths of

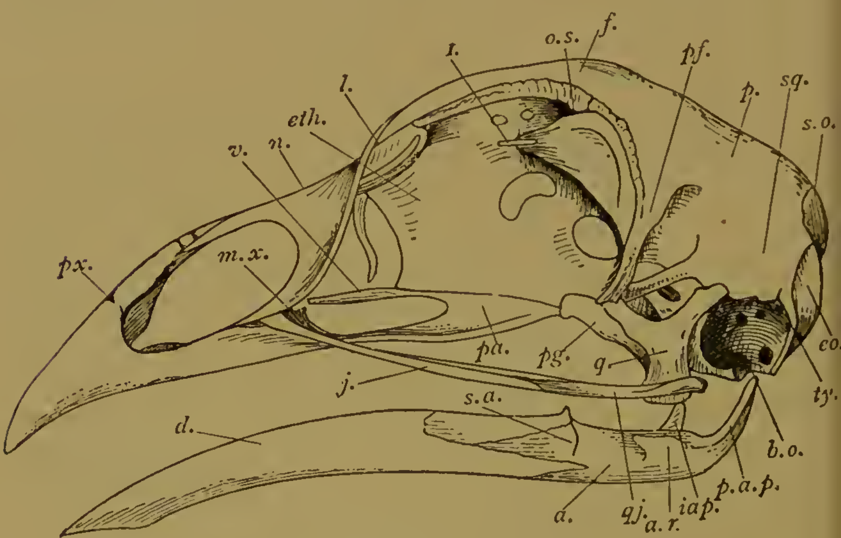

FIG. 42.—Skull of Fowl. (From Gadow.)
(For lettering, see text.)

the maxillæ, which have received a separate name, though they are not separate bones; they are termed the *maxillo-palatines.* Another arcade is formed by a chain of thin and splint-like bones connecting the quadrate with the maxilla; these are the *jugal* (*j*), nearest to the maxilla, and the *quadrato-jugal* (*qj*), articulating with the quadrate. Finally the quadrate articulates with the last of the series of membrane bones, the *squamosal* (*sq*).

There remains for consideration the first two visceral arches,

[1] As to pterygoids and palatines, see footnote to p. 96.

which, as in the frog, enter into the formation of the skull wall. The first arch, the mandibular, is formed out of the *quadrate* (*q*), above, a roughly triradiate bone. Below there is, in the young fowl, Meckel's cartilage, which is surrounded by a set of membrane bones which form the actual lower jaw of the adult; but the proximal end of the Meckel's cartilage is ossified to form the *articulare* (*a.r*)—that portion, in fact, which articulates with the quadrate. There is, however, no Mento-meckelian.[1] The membrane bones which ensheath the rest of Meckel's

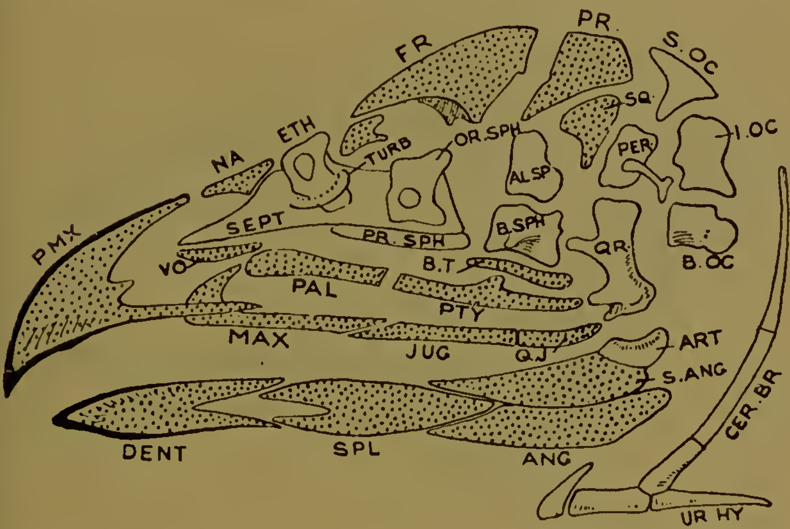

FIG. 43.—Diagram of Bird's skull. (Mainly after Gadow.)

Cartilage bones (white): B.OC, basi-occipital; I.OC, ex-occipital; S.OC, supra-occipital; PER, periotic (behind it is columella); QR, quadrate; B.SPH, basi-sphenoid; ALSP, ali-sphenoid; PR.SPH, pre-sphenoid; OR.SPH, orbito-sphenoid; TURB, turbinals; ETH, prefrontal; SEPT, ethmoidal septum; ART, articulare; CER.BR, UR.HY, hyoid bones. Membrane bones (dotted): PR, parietal; SQ, squamosal; FR, frontal; above turbinal is lacrymal (not lettered): NA, nasal; PMX, premaxilla; VO, vomer; MAX, maxilla; PAL, palatine; PTY, pterygoid; B.T, basi-temporal; JUG, jugal; QR, quadrato-jugal; DENT, dentary; SPL, splenial; ANG, angulare; S.ANG, supra-angulare.

cartilage are *dentary* (*d*), *angular* (*a*), *supra-angular* (*s.a*), and *splenial*.

The second arch is formed above by the *columella*, a rod-like bone, which is—as in the frog—associated with the auditory organ. The *hyoid bone* lies in the tongue, and consists of a basal piece and of two lateral outgrowths; of these the

[1] A Mento-meckelian ossification has, however, been discovered in a hawk.

anterior, and much the shorter one, represents the lower bit of the hyoid arch, while the posterior long and upwardly curved rods are the first branchial arch. The fowl is thus considerably further away from the primitive fish-like condition than is the frog, where there are remains of three purely branchial arches.

The general plan of the bird's skull is shown in Fig. 43, where the bones are represented diagrammatically, and in their approximate positions, but disarticulated. As with the figures

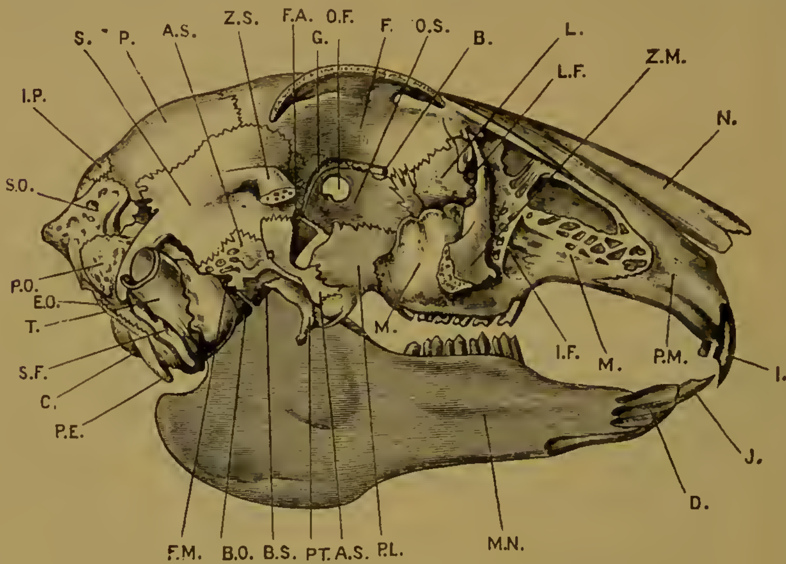

FIG. 44.—Skull of Rabbit. (For lettering, see text.)

of the frog's skull above, the membrane bones are dotted The cartilage bones are left white.

The *skull of the* **Rabbit** offers a number of differences in structure from that of the bird. The most important of these are the following :—

1. The skull articulates with the atlas by two instead of by one occipital condyle.

2. The basitemporals are absent.

3. The representative of the quadrate is a small bone within the ear, the malleus.[1]

[1] It must be borne in mind that this is only one view out of many. Some regard the articular surface of the squamosal as the quadrate, others the tympanics.

4. The lower jaw consists of a single membrane-bone on each side.

In other respects the skull of the rabbit does not differ widely in essentials, though, of course, there are numerous differences in detail. The cartilage bones of the cranium are: the four *occipitals* (B.O, E.O. S.O); in front of the basi-occipital is the *basi-sphenoid* (B.S), above and on either side of which are the *ali-sphenoids* (A.S); in front of the basi-sphenoid is the *pre-sphenoid*, above which are the *orbito-sphenoids* (O.S); in front of this again is the *mesethmoid.* The membrane bones of the cranium are the *parietals* (P) behind, which enclose a small *inter-parietal;* in front are the *frontals* (F).

Of the sense capsules, the auditory consists in the adult of a single periotic bone (P.O), which is formed in the embryo by the ossification of three tracts of cartilage, the *pro-otic*, *opisthotic*, and the *epiotic.* The membrane bones connected with the auditory capsule are the *tympanics* (T) surrounding the meatus auditorius, and the *squamosals* (S), with which the lower jaw articulates. The optic capsule has no cartilage bone or bones, but the *lacrymal* (L) may be considered to be the membrane bone connected with it. The olfactory capsules have three complicated and folded cartilage bones, the *ethmo-maxillo* and *naso-turbinals.* Of membrane bones connected with the olfactory sense-capsule are the *nasals* (N) above, and the *vomer* below.

The first, or mandibular, arch has for its upper piece the *malleus*, one of a chain of three bones, which pass between the tympanic membrane and the foramen ovale in the periotic bone; the chain serves to convey the waves of sound impinging upon the tympanum to the internal ear.

Meckel's cartilage remains unossified in the rabbit, except, perhaps, a small *Mento-meckelian* element, as in the frog. The palato-quadrate process of the first arch has no cartilage bones developed in it in the rabbit. But the membrane bones, which overlap, or are in connection with this arch, are, firstly the *palatines* (P.L) and the *pterygoids* (P.T), which together form the back part of the hard palate: and in front of, and at the outer side of these, the *maxillæ* (M) and *premaxillæ* (P.M), which bear

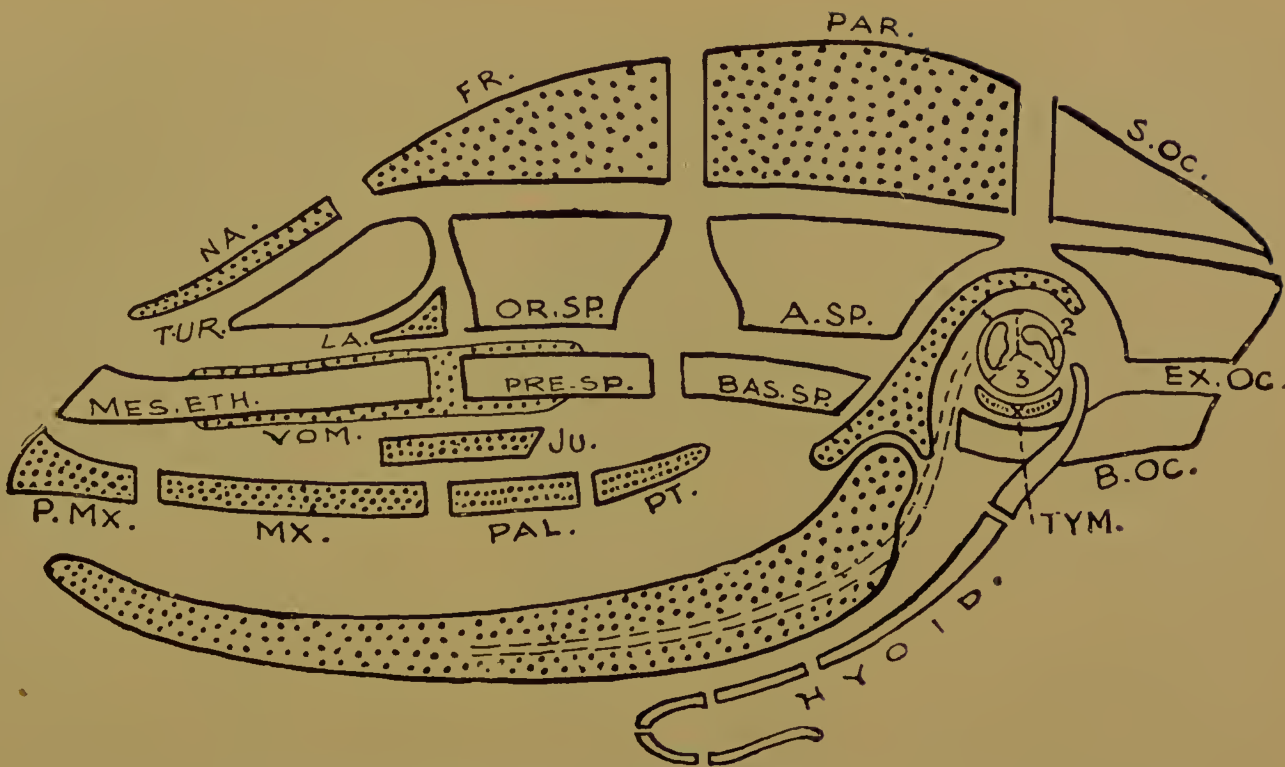

FIG. 45.—Diagram of Mammalian skull, for comparison with similar diagram of Bird's skull. (Partly after Flower.)

As before, membrane bones are dotted, cartilage bones left white. Cartilage bones (white): B.OC, basi-occipital; EX.OC, ex-occipital; S.OC, supra-occipital; 1, 2, 3, periotic (in 2 and 1 are malleus and incus); TYM, tympanic; BAS.SP, basi-sphenoid; A.SP, ali-sphenoid; OR.SP, orbito-sphenoid; PRE.SP, pre-sphenoid; MES.ETH, mesethmoid; TUR, turbinals; PAL, palatine; PT, pterygoid. Membrane bones (dotted): PAR, parietal; FR, frontal; NA, nasal; VOM, vomer; P.MX, premaxilla; MX, maxilla; JU, jugal; LA, lacrymal; MN, mandible (*i.e.* dentary), articulating with squamosal. Dotted lines, Meckel's cartilage.

the teeth of the upper jaw. The *Jugals*, which extend from the maxillæ to the squamosals, are to be looked upon as belonging to the same section of the skull. As to Meckel's cartilage, it is invested by the *dentary* bone (M.N), which, though a single bone, and thereby differing from the ensheathment of the cartilage in the bird, ossifies from a number of centres, which indicate its primitively compound nature. The number of centres appears to correspond to the number of separate bones in the bird. The second arch is represented proximally by the *incus*, the *stapes*, and the *os orbiculare*—three of the four ear-bones already referred to. The rest of the *hyoid arch* consists of a median piece, the body, and two pairs of projecting cornua, of which one is true hyoid, the other a vestige of the third visceral arch.[1]

The Skeleton of the Fore Limb.

The skeleton of the fore limb consists of the pectoral girdle and of the limb which articulates with it.

The *pectoral* or *shoulder girdle* itself in the adult **Frog** is a partly cartilaginous, partly bony structure. Each half of the girdle is C-shaped, the upper end, which does not meet its fellow, lying above the vertebral column; the lower ends do meet below. The part of the girdle lying above the *glenoid cavity*, into which fits the head of the humerus, is the scapular region. The uppermost part of this is bent at an angle with the lower part, and is not so much ossified: it is called the *supra scapula;* the lower, more ossified portion, the *scapula*. On the ventral side of the glenoid cavity are two bars of cartilage (in the young frog), which meet at first in the middle line; these are respectively the *coracoid* and the *procoracoid* (the most anterior). The extremities of the coracoid and the procoracoid of each side fuse together, the common portion being termed the *epicoracoid;* the two epicoracoids overlap. On the procoracoid, but independently of it, a membrane bone, the *clavicle*, is formed, so that in the adult shoulder-girdle it

[1] It has been shown that the cartilages of the larynx are traceable to branchial arches behind these.

appears as if there were a bony procoracoid as well as a bony coracoid; the distinctness of the anterior bony bar must be borne in mind. The so-called *sternum* of the frog consists of an anterior bit, the *omosternum*, lying in front of the coracoids, and formed by a forward growth of the epicoracoids. The hinder part of the sternum (the *xiphisternum*) is formed in-

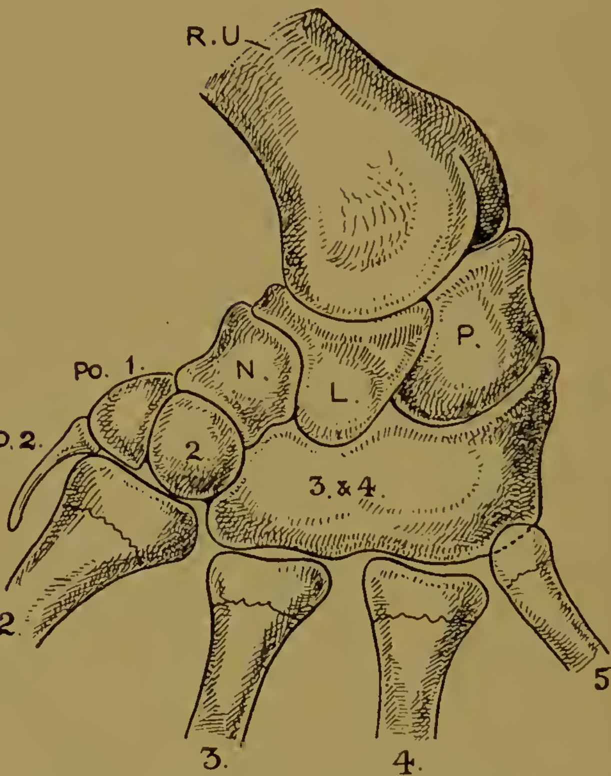

FIG. 46.—Hand of Frog. (After Howes and Ridewood.)
R.U, fused radius and ulna; N, naviculare (centrale); L, lunare (radiale); P, ulnare; P.O.1, carpal of pollex; P.O.2, metacarpal of pollex; 2–4, carpals of digits 2–4; 2–5, metacarpals.

dependently of two pieces of cartilage, which fuse into a single piece, and become partly ossified. We shall see later that this part alone can be fairly termed sternum.

The limb itself consists of a single bone, articulating with the glenoid cavity, the *humerus;* of two bones lying side by side and fused together, which articulate with this, the *radius* and *ulna*; of a number of small bones and cartilages (to be more particularly described immediately), the *carpus*; of a set of longish bones, one for each finger, the *metacarpals*; and, finally, of a number of smaller elements, still several to each finger, the *phalanges*.

Of separate carpal bones, six can be recognized in the common frog. They are arranged in two rows, a proximal and a distal. In the proximal row are three bones, of which two articulate with the radio-ulna. The innermost of these is the *ulnare*, the outermost the *centrale*. A little below the latter, but really belonging to the radius, is the *radiale*. In most animals this bone is articulated with the radius; but in the frog it has lost this primitive position. The distal row has also three bones. The first of these bears the rudimentary thumb, but also articulates with the second digit; the second articulates with the second digit only; the third is much larger, and is really formed by a fusion of two separate cartilages belonging to the two next digits of the hand.[1]

The shoulder-girdle and fore-limb of the **Fowl** differs greatly from that of the frog—a difference which is, of course, related to its very different use.

The *scapula* is a thin scimitar-shaped bone, which lies along the ribs, parallel to the long axis of the body. Below the glenoid cavity, for the articulation of the humerus, is the *coracoid*, a more solid and a shorter bone than the scapula. From the inner face of each coracoid a process grows forward, which is a rudimentary *procoracoid*. The two coracoids are implanted in grooves upon the anterior edge of the sternum. The *clavicles* are represented by a curved and U-shaped bone often termed the "furcula." It is a membrane bone, as is the clavicle of the frog.

The *sternum* of the fowl is a much more solid structure than that of the frog. It grows out below into a thin but strong keel, or carina, which serves for the attachment of the powerful pectoral muscles, which are the chief agents in the downward stroke of the wing during flight. This sternum is

[1] It is apparently very rarely the case among frogs that the fifth carpal has a cartilaginous rudiment.

formed by a growing together of the lower ends of the ribs, and cannot, therefore, have any relation to the omosternum of the frog, which, as has been said, is an outgrowth of the epicoracoid. It may, however, correspond to the xiphisternum of the amphibian, which *is* produced by the concrescence of two plates of cartilage. As ribs are wanting in the frog, it

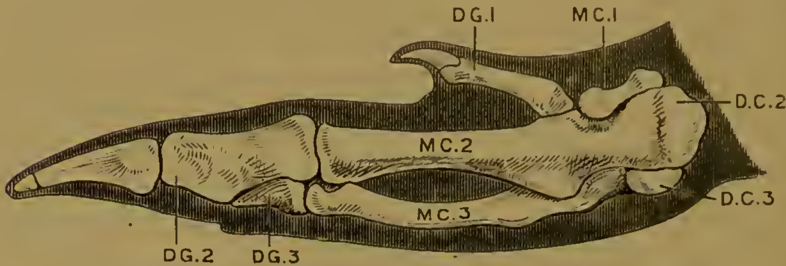

FIG. 47.—Hand of Fowl. (After Parker.)
D.C.2, D.C.3, carpals; MC.1–3, metacarpals; D.G.1–3, digits

may be that these lower bars of cartilage are the remains of formerly more extensive ribs.

With the glenoid cavity, formed by both scapula and coracoid, articulates the *humerus*. This is followed by the *radius* and *ulna*, which are here distinct bones, the ulna being the

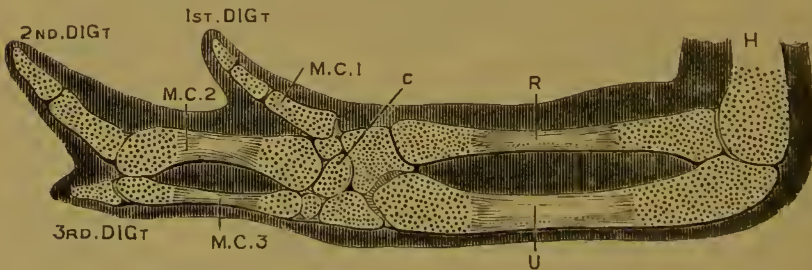

FIG. 48.—Hand of young Chick. (After Parker.)
H, humerus; R, radius; U, ulna; M.C, metacarpals; C, carpals.

longer of the two, and bowed on its outer side, where the impress of the strong remiges can often be detected.

The *carpus* of the adult bird has only two elements; but more are present in the embryo.

The hand of the fowl, as of all birds, is provided with only three fingers. Of these the three *metacarpals* are firmly welded together, with a view, of course, to allow of a strong stroke in flying; that there may be no "giving" of the constituent bones.

It will be clear, from the annexed illustrations, that the hand of the chick is much more like that of the frog than is

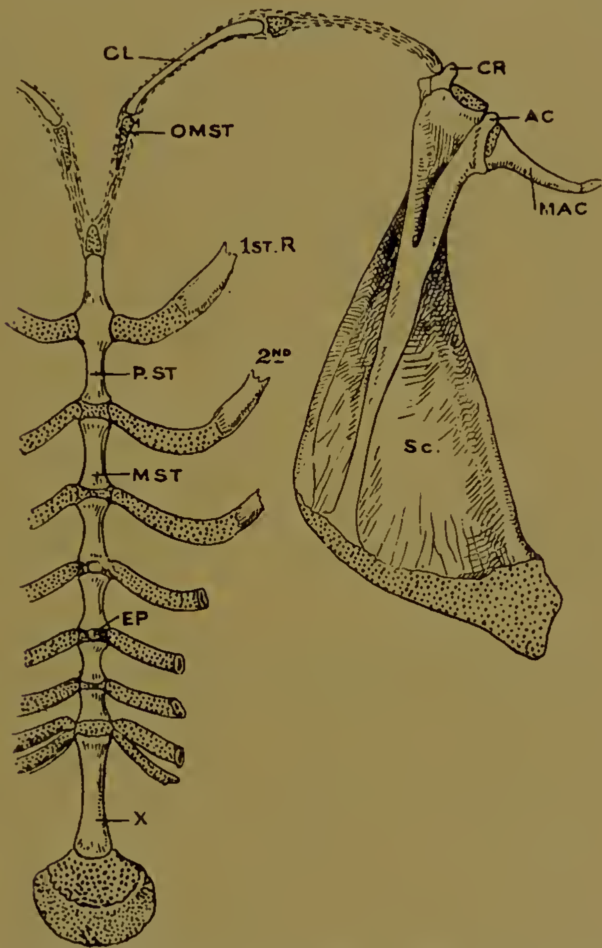

FIG. 49.—Shoulder girdle osternum of Rabbit. (From Parker; slightly altered.)
Sc, scapula; MAC, metacromion; AC, acromion; CL, clavicle; CR, coracoidal rudiments; OMST, distal coracoidal rudiment; P.ST, manubrium; MST, middle part of sternum; EP, epiphysis; X, xiphisternum; 1ST R, first rib.

the hand of the adult. The carpal bones are more numerous, and there is not so great a disproportion between the lengths of the fingers.

In the **Rabbit** the shoulder-girdle appears to consist of but a single cartilage bone, the scapula. This is a triangular bone, with a median ridge along the outer surface, ending in a process, the *acromion*. At the distal end of this is a lateral outgrowth of the ridge, termed the *metacromion*. The end of the scapula forms the glenoid cavity for the articulation of the humerus; but on the inner side of this articular cavity is a little process of bone (Fig. 49, CR), which is really ossified by two centres quite separate from the rest of the scapula. These represent collectively part of the *coracoid* of the bird; but it will be remembered that the coracoid of the bird reaches the sternum. The junction of the scapula with the sternum is effected in the rabbit by the *clavicle*, a membrane bone, and by certain ligaments. Outside the clavicle, however, fragments of cartilage (dotted in the figure) have been discovered, which seem to be bits of the otherwise missing distal part of the coracoid.

The *sternum* is a jointed bone, made up of seven separate pieces, or sternebræ, as they are sometimes called. The first of the series is the longest, and forms the *manubrium;* the last is a long slender rod, ending in a cartilaginous plate, the *xiphisternum*.

The *fore limb* itself has precisely the same divisions as in the other Vertebrata. The hand, however, has five fingers, and the *carpus* is composed of eight separate bonelets.

Skeleton of the Hind Limb.

As is the case with the fore limb, the hind limb consists of a girdle, the pelvic girdle, and of the limb attached thereto. There is, as will be seen, a very close correspondence between the several elements of the two limbs and their girdles.

The *pelvic girdle* of the **Frog** appears to consist of two separate bones, somewhat spoon-shaped, narrow in front, and expanding posteriorly into a flattened and rounded area. The narrow ends of the two are attached to the wide transverse processes of the sacral vertebra. Each of these bones is in reality composed of three separate elements. The long process and nearly one half of the rounded area is one element, the *ilium*. The ventral part of the rounded area is cartilaginous, and represents the *pubis*, while the remainder is the *ischium*. It will be observed that the three bones take a share in the formation of the *acetabular cavity*, in which is articulated the *femur*.

The **Bird's** pelvis is strikingly unlike that of the frog, and yet the same elements can be traced in it. The whole pelvic arch seems to consist of one large bone; but embryology

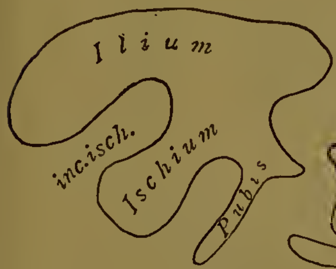

FIG. 50.—Pelvis of Chick. (From Gadow, in Newton's "Dictionary of Birds.")

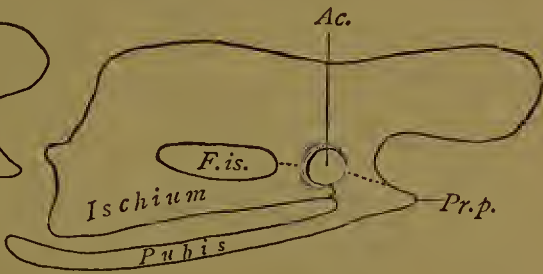

FIG. 51.—Pelvis of adult Bird. (From Gadow, in Newton's "Dictionary of Birds.")
Ac, acetabulum; *Pr.p*, prepubic process; *F.is*, ischial foramen.

shows that it is composed of a right and a left half, and that each of these, again, is made up of three separate elements. The greater part of each of the two *innominates*, as each half is called, is made by the substantial *ilium* which abuts upon the sacral vertebræ. Running backwards, parallel with the ilium, is a bone not quite so strong, the *ischium*. This is separated from the ilium in the middle by a large foramen, the ilio-sciatic foramen. Parallel with this, again, is a slender bone, the *pubis*, which is nearly quite separate from it. All three bones join to form the acetabular cavity, and in front of this the pubis gives off a small forwardly directed process, the *prepubic process*.

In the **Rabbit** are the same three bones, which again share in the formation of the acetabular cavity; or, to speak more accurately, the part of the apparent pubis within the acetabulum ossifies separately as a small *cotyloid* bone. The two *pubes* unite below to form the pubic symphysis. The totally disproportionate *ilium* in the bird, and possibly in the frog, also seems to bear some relation to the bipedal mode of progression. By its extension forwards the ilium grasps more firmly the welded sacral vertebræ, and thus gives a firmer support to the hind limbs.

The hind limbs of all these animals consist of a *femur*, corresponding to the humerus of the fore limb, followed by a

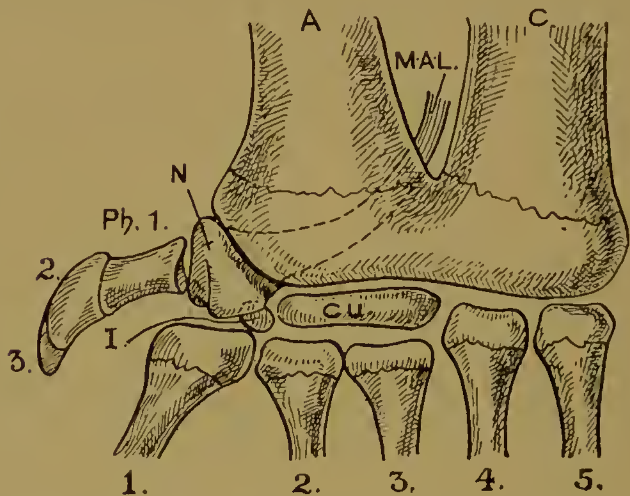

FIG. 52.—Foot of Rana temporaria. (After Howes and Ridewood.)

A, astragalus; C, calcaneum; N, naviculare (centrale); CU, cuboid (= fused distalia 2, 3); Ph, 1, 2, 3, prehallux (calcar); 1, distale; MAL, tendon of adductor longus primi digiti muscle; 1–5, digits.

tibia and *fibula*, equivalent to the radius and ulna, a *tarsus* corresponding to the carpus, a *metatarsus* and *phalanges* which have also their equivalent in the fore limb. The *femur* of the **Frog** is curved in a slightly S-shaped curve. The *tibia* and *fibula* are here fused together to form an apparently single bone. The two proximal bones of the tarsus, known respectively as the *astragalus* and *calcaneum*, are greatly elongated. This state of affairs seems to be correlated with the leaping of the amphibian, for a similar modification is to be found in the jumping Jerboa. The distal rows of tarsal bones are cartilaginous, and there are five complete toes, with a rudiment of a sixth, in the form of a small bone known as the *calcar*.

The *hind limb* of the Bird differs in several important particulars from that of the frog. The *femur*, to begin with, is much shorter than the *tibia*; the *fibula* is rudimentary, and does not reach far down the tibia. This bone, the tibia, is followed by a long bone, with which the four toes articulate. Thus the *tarsus* appears to be wanting. As a matter of fact, a study of the immature chick shows that what is apparently the tibia, is really the tibia *plus* the proximal elements of the tarsus; and what appears to be the *metatarsus* is really the three-fused metatarsals, *plus* the distal elements of the tarsus. Thus the ankle-joint is not, as it is in the frog and in the rabbit, between the end of the tibia and the tarsus, but in the middle of the tarsus. Hence it is more correct to apply the terms "tibio-tarsus" and "tarso-metatarsus" to the long bones in question. The metatarsal part of the tarso-metatarsus contains, fused together, only three out of the four metatarsals, those corresponding to the three long toes. The short hallux (or great toe) has a small metatarsal, loosely attached to the end of the tarso-metatarsus. The bird is bipedal in its progression, as is the frog to all intents. But the required elongation of the limb is brought about in the bird by the elongation of the tibia and the metatarsus, not of the astragalus and calcaneum.

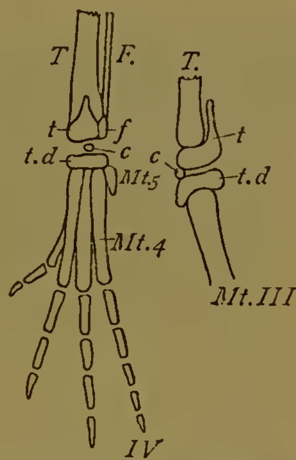

FIG. 53.—Hind foot of Bird. (From Gadow, in Newton's "Dictionary of Birds.")

T, tibia; *F*, fibula; *t*, tibiale; *f*, fibulare; *c*, centrale; *t.d*, distal tarsalia; *Mt*, metatarsals. The right-hand Fig. is a lateral view.

In the Rabbit the *tibia* and the *fibula* are complete, though the tibia is the larger of the two. The tarsus consists of seven separate bones. In the proximal row are the *calcaneum* and *astragalus*; in the middle is the *cuboid*; the distal row is formed by the *navicular* inside, and by three *cuneiforms* following it. There are only four digits in the foot of the rabbit.

Integumental Structures.

Skin structures are either purely epidermal, or partly epidermal and partly dermal.

Purely epidermal structures are feathers, hairs, claws, and the scales of birds (on the feet) and reptiles. They are formed by a modification of the cells of the epidermis only, the lower-lying dermis not actually entering into their formation.

The frog is totally devoid of any such structures, its smooth skin producing no hairs, feathers, or claws. The rabbit, like

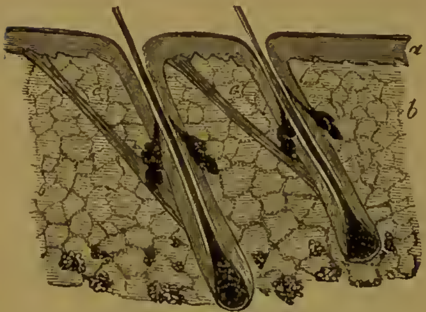

Fig. 54.—Section of the skin of the head, with two hair-follicles. Diagrammatic. (Kölliker. From Quain.)

a, epidermis; *b*, corium; *c*, muscles of the hair-follicles.

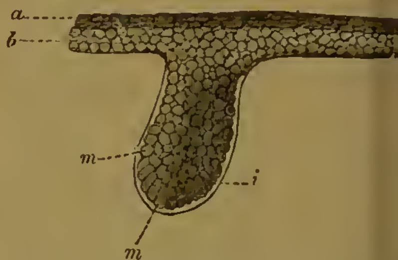

Fig. 55.—Hair-rudiment from an embryo six weeks, magnified 350 diameters. (Kö liker. From Quain's "Anatomy.")

a, horny, and *b*, mucous or Malpighian lay of cuticle; *i*, limitary membrane; *m*, cel (some of which are assuming an oblon figure) which chiefly form the future hair.

all other mammals, is provided with **hairs** which completely cover the body, and are even found in the mouth cavity; since, however, the inside of the cheeks is formed in the embryo by an ingrowth from the outer covering of the body, it is not surprising to find that those cells which have thus grown inwards have retained the power of becoming modified into hairs. The first appearance of a hair is a slight thickening of the lowest layer of the epidermis, the stratum malpighii; this growth projects downwards, and becomes larger. Ultimately the central cells change their character and become horny, thus forming the hair itself, while some of the peripheral cells grow out into little sac-like structures, which are the *sebaceous glands*, always attached to hairs, and secreting an oily fluid. A slight papilla of the underlying dermis projects into the centre of the hair, but takes no aetual part in its formation, merely serving to bring eloser the necessary blood-vessels and nerves.

If the skin of a bird be carefully examined, there will be found among the feathers thin and delicate horny shafts, which have every resemblance to hairs. But between these filo-plumes and the most complieated feathers, every intermediate stage will be found; and even the filo-plumes themselves have commonly a few slight branches at the summit.

At its origin, however, a feather—even these simplest feathers—is different from a hair. It appears first as a slight outgrowth, a papilla, of the skin. This is surrounded by a depression, out of the middle of which the papilla arises. The papilla consists both of dermis and epidermis; but the epidermis alone enters into the formation of the feather, the dermis beeoming the central pulp, with blood-vessels, nerves, etc. The surrounding fossa deepens, and thus the developing feather comes to lie at its base within a sheath. The feather itself is formed purely by a horny change in the epidermie cells, which are separated into three layers. The outermost layer forms a delicate sheath, which is east off when the feather is fully formed, but which may be often seen encasing a newly formed feather in a moulting bird; the middle layer forms the feather itself, whose complieated form is due to the irregular modification of the cells, as will be explained directly, while the innermost layer of all forms that series of eup-shaped bits which oeeur in the inside of the quill, and to which the Germans have given the poetical name of "Federseele." A feather itself, when most fully developed, such as one of the strong *remiges* which fringe the wing, or *rectrices* which form the tail, or contour feathers, as the strong feathers of the general body surface are called, eonsists of a quill, or *calamus*, which is hollow, and of a *rhachis* above this; at the junetion of the two is a minute perforation, the *umbilicus*, and at this point a small

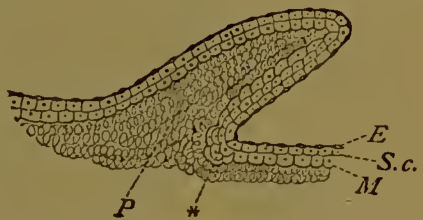

FIG. 56.—Feather papilla. (From Gadow, in Newton's "Dictionary of Birds.") *P*, pulp; *E*, *S.c.*, *M*, different layers of epiderm.

second feather often arises from the main shaft; this is the *after-shaft.* The rhachis gives off numerous *barbs*, which in

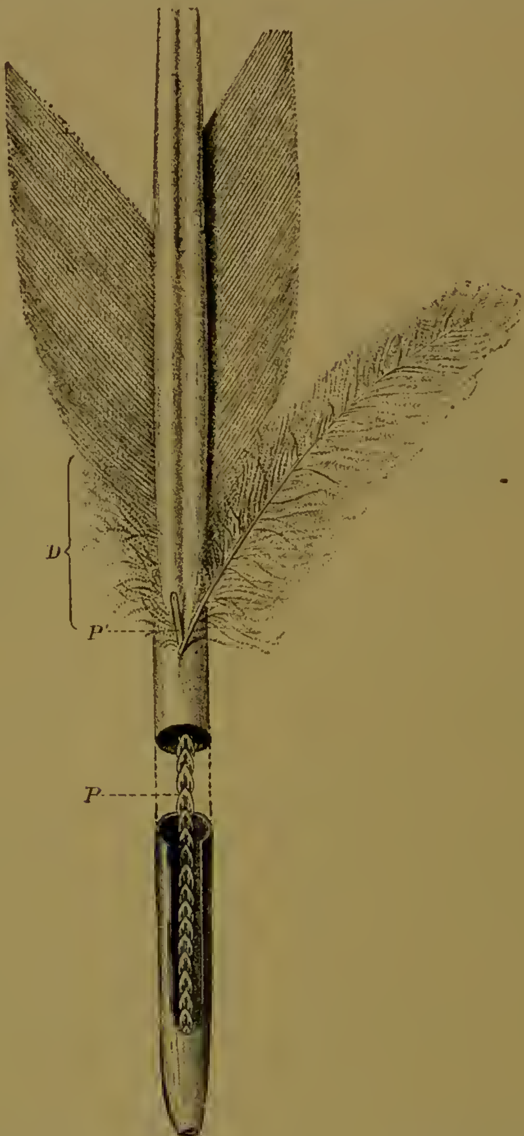

FIG. 57.—Feather. (From Gadow, in Newton's "Dictionary of Birds.")
D, downy portion; *P*, horny cap ("Feder selle"), continued through umbilicus as *P'*; to right of this springs aftershaft.

turn give rise to secondary branches, the *barbules*, and these again to shorter processes, the *barbicels*, which are often hooked at their extremities, and so interlock with neighbouring feathers. Thus the firm nature of a feather is arrived at.

Down feathers, which are, as their name implies, the softer feathers of the body, frequently do not possess the terminal hooks—the *hamuli*, as they are sometimes called—and therefore do not interlock, hence their softness. Moreover, in down feathers, the barbs frequently arise in a clump from the calamus, the rhachis being absent.

The quill, of course, is formed by being moulded upon the feather papilla; but in the natural position the rhachis, with its branches, is folded so that the extremities of the barbs meet, thus forming a cylinder above: the umbilicus forms the communication between this and the cavity of the quill. The feather itself is, therefore, simply a continuation of the quill cylinder, with an irregular cornification, incomplete in the middle dorsal line, the end, therefore, becoming free directly the feather is fully formed. When an after-shaft is present, it is formed on the opposite side of the feather papilla from the main rhachis.

FIG. 58.—A down feather. (From Gadow.)
Sh, sheath.

While the scales of lizards and of birds are purely epidermic structures, those of fishes are either mesodermic or are formed by both epidermic and mesodermic elements. The minute scales of the dogfish, which, together with the intervening skin, form the substance known as shagreen, consist of a base of dentine—formed by the mesoderm, and similar in its characters to the dentine of the teeth of the same animal—and of a cap formed by epidermis, which is, in its turn, like the enamel of the teeth. The identity of structure between these body scales and teeth has led to the inference that they are identical, homologous, structures. At first sight it may appear difficult to compare structures lying on the outside of the body with the teeth lying in the interior of the mouth; but remembering the hairs, purely skin structures, which line the cheeks of the rabbit, it will not be difficult to see that in the case of the dogfish also we have simply to do with an involuted part of the skin, *i.e.* the mouth cavity, whose lining epidermis and dermis has retained the functions of those two layers elsewhere. Just as the teeth are in most animals attached to bones of membranous, not cartilaginous origin, so the base of these scales are ossified. Each scale, therefore, of a shark is literally a tooth attached to a small bone.

The comparison of teeth with scales is supposed to hold good up to the Mammalia. But it must be borne in mind that the mammalian tooth consists, in addition to enamel and dentine, of a layer of bone, the so-called cementum. This may be even preformed in cartilage. It has nothing whatever to do with the bone of the jaw to which the teeth ultimately become attached. This general statement, therefore, "The bones around the mouth have been recognised as having their origin in tooth-bearing plates derived from fused placoid plates," must be, possibly, somewhat cautiously accepted. It looks, in the case of the Mammalia, at any rate, as if the dentary and other membrane bones which bear the teeth were not the precise equivalents of the fused bony bases of placoid scales, since the homologues of the latter exist (?) in the cementum of each tooth.

Teeth are found in the frog and in the mammal; but there is no bird in which these structures occur living at present. There were formerly toothed birds; and some of their descendants of to-day have retained rudiments, shown during the development of the jaws, which are regarded by some, though not by all, anatomists, as rudimentary tooth germs.

In the frog the teeth are developed upon the maxillæ, premaxillæ, and vomers; in the rabbit, upon the two former bones and upon the dentary of the lower jaw. The teeth of the frog are all of approximately the same shape and size; they are, moreover, very numerous, and fresh teeth are formed when the first ones get worn out. In the rabbit, on the contrary, the teeth are fixed in number, and only a few; they are varied in form,[1] the chisel-like incisors being easily distinguishable from the flat grinding teeth, while most mammals have, in addition, the sharper canines lying between the incisors and premolars. Furthermore, there are only two

[1] "Homodont" and "Heterodont" are the terms used to express the condition of the teeth in the frog and rabbit respectively.

sets of teeth, the first set being termed the *milk dentition*,[1] and the last the *permanent dentition*. The permanent incisors and the first few molars, on this account termed premolars, have predecessors in the milk dentition. The arrangement of the teeth in mammalian jaws is commonly expressed by dental formulæ, which serve to show at a glance the number of the teeth and their nature. Only one side of each jaw is taken in representing the teeth, so that the number as given in the formulæ must be doubled in order to give the full number. The milk dentition of the rabbit is represented by the following formula: *di.* $\frac{2}{1}$, *dc.* $\frac{0}{0}$, *dm.* $\frac{3}{2}$; the permanent thus: *i.* $\frac{2}{1}$, *c.* $\frac{0}{0}$, *pm.* $\frac{3}{2}$, *m.* $\frac{3}{3}$. *i.*, *c.*, *pm.*, *m.*, respectively stand for incisors, canines, premolars, molars; a *d* before each of these letters means deciduous, or milk incisor, etc.

[1] Diphyodont is the technical term for a mammal with two sets of teeth.

CHAPTER XI.

THE EGG, THE SPERM, AND THE DEVELOPMENT OF THE CHICK.

EGG.

THE fowl's egg, in spite of its size, is a single cell, just as is the microscopic egg of the earthworm. It is wrapped, however, in an adventitious sheath, derived from the walls of the passages through which it makes its way to the exterior when "laid." The real egg—the term *ovum* is preferable, as not implying the non-essential coverings—is limited to that part of the egg which is popularly called the yolk. All outside of the delicate membrane covering the yolk is the adventitious sheath. This sheath consists of the "white," or albumen, which is fluid in the fresh egg, has two spiral thickenings at each pole, the so-called "chalazæ," the use of which is, apparently, to act as springs to prevent the delicate ovum itself from being jarred and ruptured. Outside of the albumen is a tough membrane, and outside that, again, the shell. The albumen is absorbed by the growing chick; the numerous pores in the shell permit of respiration being carried on before the young chick breaks through the eggshell at hatching. The ovum proper is enclosed by a delicate and elastic *vitelline membrane.* The substance of the ovum is chiefly made up of the yolk; but there is a cap of pure protoplasm at one side, in which lies the *nucleus* or *germinal vesicle.* The great size of the ovum is due to the enormous quantity of this yolk present.

Ova are classified according to the quantity of yolk present and its distribution. There are three grades, connected, of course, by intermediate conditions.

The *alecithal* ovum (*e.g.* Earthworm, *Amphioxus*, Rabbit) is a minute egg, with only a little yolk in the form of a few spherules scattered uniformly through the protoplasm.

The *telolecithal* ovum (*e.g.* Fowl, Dogfish) has a quantity of yolk massed at one pole, and occupying the greater part of the ovum.

The *centrolecithal* ovum, finally (e.g. *Astacus*), has a quantity of yolk, which lies centrally, and is surrounded by a peripheral layer of protoplasm.

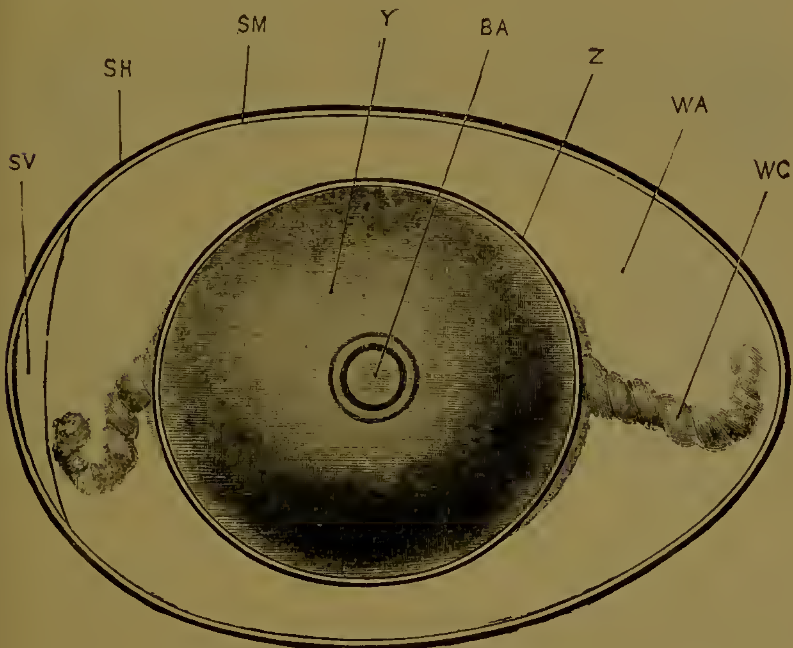

FIG. 59.—Egg of Fowl in longitudinal section. (From Marshall.)
BA, germinal disc ; Y, yolk ; Z, vitelline membrane ; WA, albumen ; WC, chalaza ; SV, air space ; SM, shell membrane ; SH, shell.

The frog's egg is intermediate between the alecithal and the telolecithal; there is a great deal, but not an enormous quantity, of yolk, which is more dense at one pole than at the other, though the protoplasmic pole of the ovum is not entirely free from yolk, as in the fowl.

Alecithal ova either produce embryos which are hatched and lead a free larval life at a very early period of development, as in the case of *Amphioxus*, or the embryo, if not hatched until it is full grown, as in the earthworm and rabbit, has some special means of nutrition independent of the yolk contained in the ovum. The earthworm embryo lives upon the albumen in the cocoon; the young rabbit is nourished by the mother through the placenta. On the other hand, the animals hatched out from eggs with abundant yolk are nourished during growth by that yolk, and are born in a more or less adult condition, as in the case of the chick. The frog is intermediate; the larva is older when it leaves the egg than that of the Amphioxus. Some frogs are not hatched as tadpoles, but as frogs; this is due to a larger and, consequently, more yolk-laden ovum.

If there were any doubt as to the unicellular character of the ovum from an examination of its structure when mature, this doubt would be entirely removed by the mode of development of the ovum.

The ova in the very immature ovary can be detected as cells only a little larger than the other cells which form the tissue of the ovary. The larger cells, destined to become ova, are surrounded by a layer which ultimately becomes several layers thick of the smaller, non-generative cells; this layer is termed the *follicle*, and its cells contribute to the nourishment of the egg cell. In certain animals processes of these cells have been seen to grow out and come into contact with the protoplasm of the ovum; and it has even been asserted, though the view is not generally accepted, that the yolk is actually elaborated in these cells, and then, as it were, eaten by the ovum.

Comparison of the Ovum with an ordinary Tissue Cell and with the Simplest Animals.

It has at various times been attempted to be shown that eggs in some cases are not single cells. It may, however, be taken for granted that the ovum is invariably a single cell. The main reasons for this conclusion as to the morphological nature of the ovum are as follows: In the first place, the young ova, in most cases, are perfectly indistinguishable from cells that do not become ova. Secondly, the structure of the mature ovum agrees in every point with that of a single cell: it is made up of a mass of protoplasm in which is imbedded a nucleus; the reticular structure of the protoplasm and of the nucleus is exactly paralleled in other tissue cells; and, finally, the cells of many tissues (all, probably, according to some histologists) possess a centrosome—that body which plays so important a part in cell division. Thirdly, the way in which an ovum divides is like that of other cells; the complicated

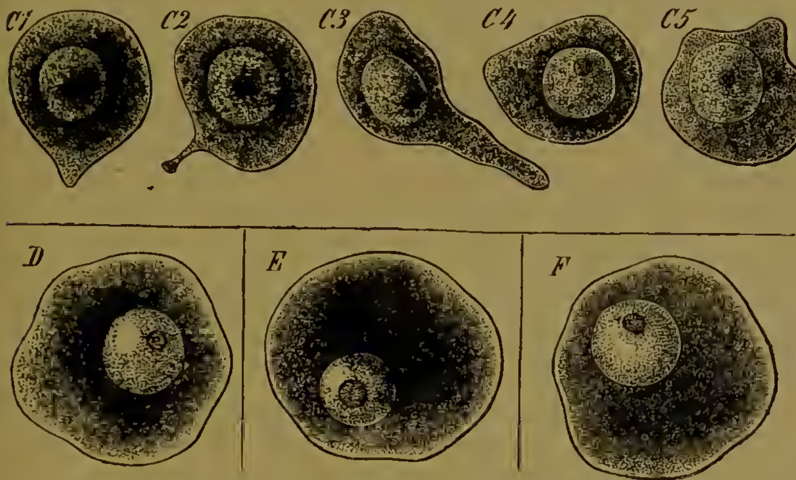

FIG. 60.—Amœboid movements of young egg-cells.
C1 to C5, egg of a Cat, in five successive stages (after Pflüger); D, ditto of trout; E, of a Hen; F, of Man.

process of Karyokinesis is copied, so to speak, in the ovum (cf. Figs. 64, 65), detail for detail, from the method of other cells. It is true that in many cells a simpler mode of cell division, not found in ova, is often met with, *i.e.* direct or amitotic division, in which the nucleus simply constricts and divides, without the complicated figures of Karyokinesis (or Mitosis, as it is sometimes termed); but the indirect method is the more characteristic mode of division of cells in general.

Another highly important generalisation to be borne in mind in considering the single-celled character of the ovum is its consequent likeness to a single-celled organism, such as an Amœba. The body of the most advanced animal is derived from a single cell, just as we suppose that the ancestor of all the higher animals was a single-celled organism. Moreover, the eggs of many animals exhibit amœboid movements; and the encystment previous to division of Protozoa, is paralleled by the secretion of a membrane by the ovum when it is ready to divide.

Maturation of the Ovum.

The egg, then, is a single nucleated cell, which only differs, and that not always, from other animal cells by its greater size and storage of yolk, the two characteristics being responsible for each other.

Except in the comparatively rare cases of parthenogenesis, an ovum must be fertilised by a spermatozoon before it can divide, and by its repeated divisions form an embryo.

The hen's egg, on account of its large size and the difficulty of manipulating the yolk, has not been thoroughly studied in the stages of its development preceding fertilisation. The following account is therefore a general account, which, with slight differences in detail, will no doubt serve as a description of the processes that occur in the fowl's egg.

The nucleus is a vesicular structure surrounded by a definite membrane, and in which there is a network of denser and darkly staining matter—on this account termed chromatin—in the meshes of which is a more fluid substance. The general term " chromatin " has been given to the meshwork in general, but it appears that the meshwork is formed of a groundwork of *linin*, to which are adherent granules of *nuclein*. It is important to distinguish between these two substances, because their behaviour is different, as will be seen shortly, in the maturing and dividing ovum. Just before the ovum is ready for fertilisation the nuclein masses itself into a number of short rods, to which the name of *chromosomes* has been given. The linin arranges itself in the characteristic form of a spindle, as is shown in the annexed figure; the membrane of the nucleus has in the mean time disappeared, and at the two poles of the spindle are two rounded bodies whose origin and fate is at present a mystery, but which have been called the *centrosomes* : from the centrosomes radiate a number of lines of granules of the egg protoplasm into the surrounding mass.

The entire nucleus advances towards the periphery, and half of the chromosomes, together with a portion of the spindle, separates itself from the egg, and remains at the surface as the *first polar body*. A *second polar body* is then protruded, and the ovum

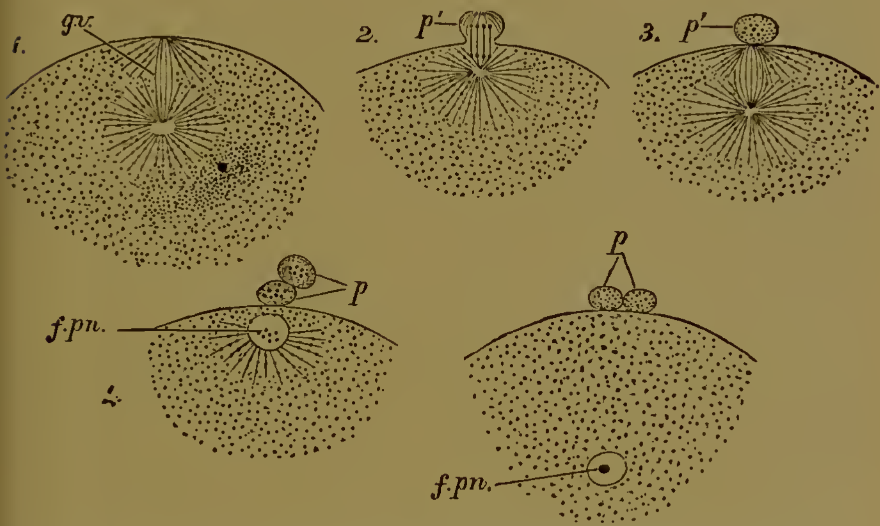

FIG. 61.—Stages in the formation of polar bodies in the ovum of a Starfish. (After Hertwig.) *g.v.*, germinal vesicle transformed into a spindle-shaped system of fibres ; *p'*, the first polar body becoming extruded ; *p*, *p*, both polar bodies fully extruded ; *f.pn.*, female pronucleus, or residue of the germinal vesicle.

after this is ready for fertilisation. The extruded polar bodies play no further part ; they remain for some time, and ultimately disappear. Their nature will be discussed later.

HISTORY OF THE SPERMATOZOA.

The spermatozoa of animals are very different from their ova. While the ova are always relatively large, sometimes enormous, lethargic, showing at most amœboid movements, the spermatozoa are minute, and nearly always actively motile. Even where they are immobile, as is the case with the Crustacea, their form is different from that of the ova, and they are greatly smaller.

In spite, however, of these differences, which are as marked as those which occur between the cells of the most diverse tissues, there are abundant reasons for regarding the ova and spermatozoa as equivalent and homologous bodies. In the first place, and apart altogether from the special resemblances that will be pointed out in their development, they are both cells. In each is a nucleus, and the nucleus is accompanied by protoplasm. In the case of the ovum the protoplasm has given rise to more or less yolk, and it is consequently inert. The spermatozoon consists of a "head," which is the nucleus; and the protoplasm of the cell has been mainly converted into the actively vibratile "tail." A spermatozoon, in fact, may be looked upon as a flagellate cell in which the flagellum has acquired undue importance. The general correspondence between ovum and spermatozoon is better shown by those rare cases (the Nematoid worms) in which the spermatozoon is not flagellate, but moves by thrusting out pseudopodia.

As to the special resemblances between ova and spermatozoa, they are both produced in identical "glands," the gonads. The gonads, whether male or female, are always local proliferations of the lining membrane of the cœlom. In the tadpole, for example, as an instance of an animal with separated sexes, the gonads appear as a pair of ridges of the peritoneal epithelium, the genital ridges, which are at first absolutely indistinguishable. In hermaphrodite animals either both ova and sperm are produced from the same gonad (*e.g.* snail), in which no need arises for a comparison, or if two kinds of gonads are present they are clearly homologous. Thus in the earthworm the testes and the ovaries occupy identical positions in the body. Moreover, they appear to correspond exactly in number, for, although the adult worm has two pairs of testes and one pair only of ovaries, there is in the embryo a fourth pair of gonads in the twelfth segment. There is thus a close correspondence, usually amounting to identity, in the situations where the ova and spermatozoa are produced. There is, furthermore, an exceedingly close likeness in the way in which the ova and the spermatozoa respectively develop in those gonads.

As to sperm formation, the details vary in different animals, but an instance selected will serve to illustrate the facts upon which it is necessary to lay stress. The nucleus of the sperm mother cell undergoes what is called a "reducing division;" that is to say, there are at first twenty-four chromosomes, which are divided into two lots of twelve each when the original cell has divided into two; in the product of the next division each of the four cells formed has a nucleus containing only six chromosomes. Now, when this state of affairs is compared with what occurs in the ovum, it is plain that it is not strictly comparable with the division of the ovum after fertilisation, for when that occurs each chromosome in the nucleus divides by splitting, so that each daughter nucleus has the same *number* of chromosomes as the parent nucleus, though each separate chromosome is but half that of the parent nucleus. But during the formation of the polar bodies events occur which are exactly comparable to that of the sperm cells. Each of the two polar bodies is formed by a reducing division. What has happened in the ovum, therefore, is a division of the egg mother cell into three or four daughter cells, of which, however, only one becomes an ovum. In the case of the sperm all the daughter cells become spermatozoa.

Fertilisation of the Ovum.

The mature spermatozoon is a tadpole-like body with a head "resembling a conical bullet," a neck composed of a small sperule, and a long vibratile tail. The head consists of nuclein. By the active lashing of the tail the spermatozoon approaches the ovum—which in the starfish (see Fig. 61), a classical object for the study of the processes of fertilisation, protrudes a little hillock of protoplasm to meet it—and bores its way into the interior, the tail in some cases remaining behind. Occasionally (Fig. 63) more than one spermatozoon enters the ovum. Directly it enters, the ovum secretes a delicate membrane, which prevents the entrance of another spermatozoon. The head of the spermatozoon (composed, it will be remembered, of nuclein) is termed the *male pronucleus.* In front of it, as it pushes its way towards the *female pronucleus* (original nucleus of egg-cell minus the polar bodies), is a small clear body round which the granules of the egg protoplasm are beginning to arrange themselves in a radiating fashion, which is the product of the neck of the spermatozoon, and has been called the *male centrosome.* The female pronucleus has a corresponding centrosome. The two pronuclei now approach more

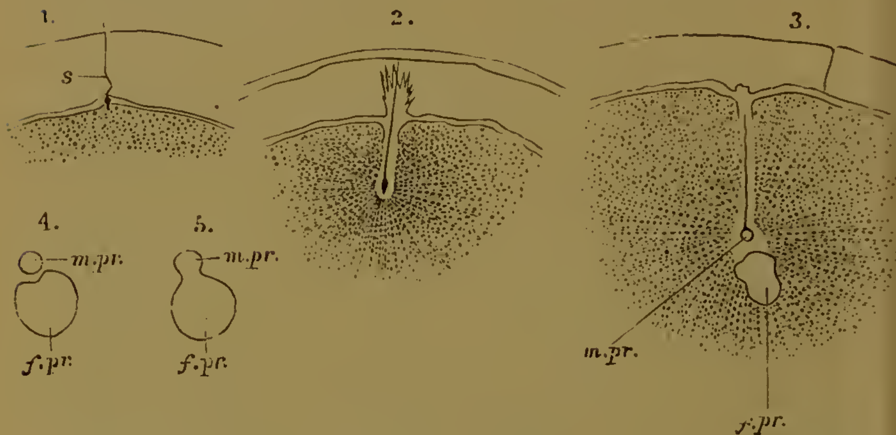

FIG. 62.—Fertilization of the ovum of an Echinoderm. From Quain's "Anatomy," after Selenka.)

S, spermatozoön; *m.pr.*, male pronucleus; *f.pr.*, female pronucleus.

rapidly, and fuse together. The centrosomes each divide into two; each half unites with the half of the other. Their movements have been fancifully termed "the quadrille of the centrosomes." The definitive nucleus is now formed, and it has, it will be observed, a centrosome at each end.

Thus the process of fertilisation is essentially the union of the nuclei of two dissimilar but homologous cells, of which one, the male, is small and active, the other, the female, is large and passive.

Division of the Ovum.

The fertilised ovum now proceeds to divide into two. This process is initiated by the nucleus; but the *modus* *operandi* is a little different from the process which accompanies the production of the polar bodies. I have said that the process is initiated by the nucleus; as a matter of fact, it appears, at least often, to commence with the division of the centrosome; but the two statements are not at present irreconcilable, for, after all, the centrosome is not at the time thoroughly understood. When the centrosome has divided,

FIG. 63.—Ovum of an earthworm, showing entrance of three spermatozoa, marked by a whirlpool-like disturbance of the ovum. (After K. Foote.)

the chromosome bodies are formed in the nucleus as before, and lie across a spindle (Fig. 64, *b*); the number of chromosomes is, in cases where they have been carefully observed, constant and characteristic for a given cell. The chromosomes constantly acquire a V shape, the angle of the V lying towards the centre of the nuclear sphere, the ends being thus peripheral. Now, the process of division of the nucleus does not consist, as in the formation of the polar bodies, by a passing over of half of the chromosomes to the daughter nucleus; but each chromosome splits longitudinally into two parts, and the result is that each of the two nuclei formed out of the original single nucleus contains exactly the same number of half chromosomes. The remaining divisions of the cell go on precisely the same way.

In the fowl's egg the division is limited to the germinal disc. The first furrow formed runs across the disc, but does

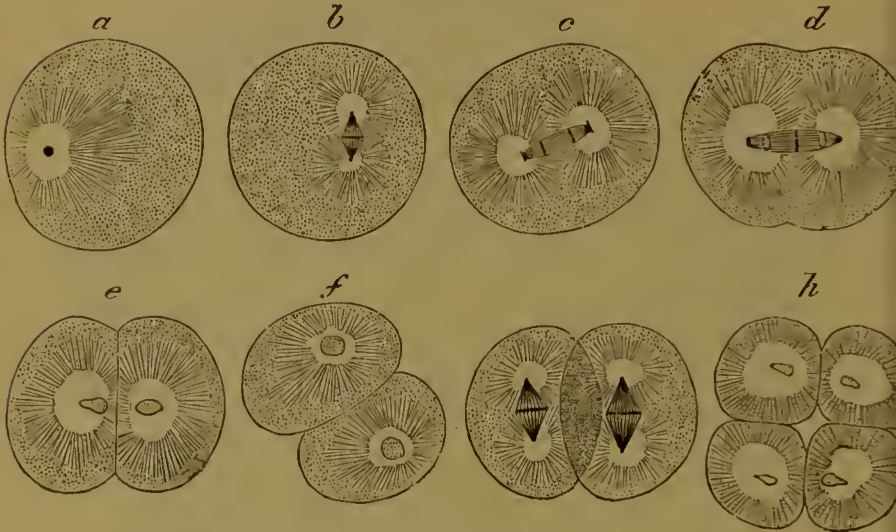

FIG. 64.—Successive stages in the division of the ovum, or egg-cell, of a worm. (After Strasburger.)

a to *d* show the changes taking place in the nucleus and surrounding cell-contents, which result in the first segmentation of the ovum at *e*: *f* and *g* show a repetition of these changes in each of the two resulting cells, leading to the second segmentation stage at *h*.

not quite reach its margin on either side; the second furrow is at right angles to this, and in the same way does not reach the edge. Finally, the disc is broken up by a series of subsequent furrows into a mosaic, which is limited to the central region of the germinal disc, and is slightly excentric. At first this cap of cells, thus formed, is a single layer in thickness, the segmentation being confined to the superficial layer of the germinal disc. Later on the segmentation takes place also in the deeper layers of the germinal disc, so that ultimately a cap of cells, two or three deep, is formed. Of these layers the outermost is soon separable for the deeper layers, and between it and them a cavity—the **blastocœl**—appears. The outer

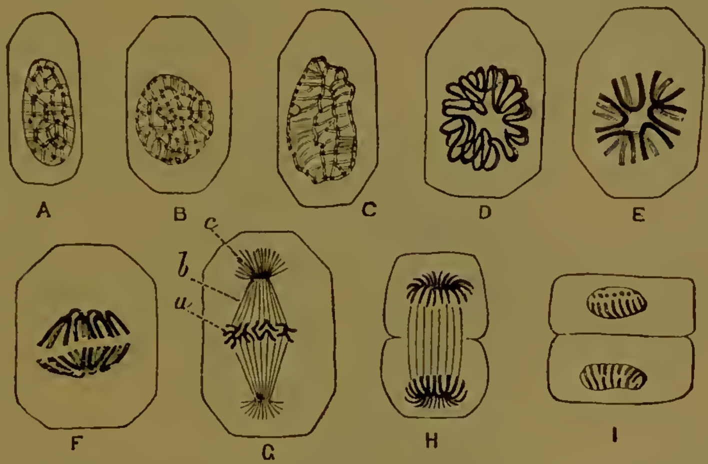

FIG. 65.—Karyokinesis of a typical tissue-cell (epithelium of Salamander). (After Flemming and Klein.)

The series from A to I represents the successive stages in the movement of the chromatin fibres during division, excepting G, which represents the "nucleus-spindle" of an egg-cell. A, resting nucleus; D, wreath-form; E, single star, the loops of the wreath being broken; F, separation of the star into two groups of U-shaped fibres; H, diaster or double star; I, completion of the cell-division and formation of two resting nuclei. In G the chromatin fibres are marked *a*, and correspond to the "equatorial plate;" *b*, achromatin fibres forming the nucleus-spindle; *c*, granules of the cell-protoplasm forming a "polar star." Such a polar star is seen at each end of the nucleus-spindle, and is not to be confused with the diaster H, the two ends of which are composed of *chromatin*.

layer thus definitely established is known as the **epiblast** (Fig. 66); the remaining cells may be termed, for the present and

FIG. 66.—Blastoderm of Hen's egg at time of laying. (From Marshall.)

E, epiblast; H, hypoblast; N', nucleus in yolk, round which a cell will be formed later; ZL, lower layer cells; BV, subgerminal space; Y, yolk.

collectively, the **lower layer cells**. These are increased by new cells out of the yolk (N, Fig. 66).

The next important change to occur is the welding together of the lowest layer of shells to form a continuous sheet, to which the name **hypoblast** is applied. Between the hypoblast and the epiblast are a few cells which take part in the formation of the third layer of the embryo, the **mesoblast.** Soon a median opacity appears along the embryo, the **primitive streak.** This, when examined by means of transverse sections, is seen to be due to a thick band of cells, which is marked superficially by a groove. The thickened band of cells is produced by a rapid growth of the epiblast cells, which results in a sheet of tissue, as is shown in the accompanying figure (Fig. 67).

This is the main portion of the mesoblast, the rest being produced from the proliferation of hypoblast cells; and some of

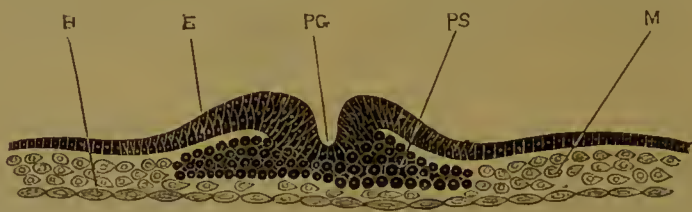

FIG. 67.—Section through primitive streak of Chick at 20th hour. (After Marshall.) PS, primitive streak; PG, the groove upon it; E, epiblast; M, mesoblast; H, hypoblast.

its cells are persistent lower-layer cells, already referred to as left after the separation of the hypoblast.

Among the cells proliferated off from the hypoblast to form the mesoblast, a number form themselves into a densish rod of tissue, running along the body of the embryo. This rod of tissue is the **notochord**, which is formed, it will be observed, from the hypoblast. The notochord is the first part of the skeleton to appear. Directly after the appearance of the notochord, the first beginnings of the central nervous system are laid down. In front of the primitive streak is a thickened layer of epiblast, the neural plate. A groove, the **neural groove**, is formed along its surface, which becomes, later, closed to form a canal, the neural tube. The closure of the groove into a tube commences with the head end and spreads backward. The cavity of the central nervous system persists in the adult as the ventricles of the brain and the canal of the spinal cord. It must be noted that the brain and the spinal cord arise as a continuous structure, and that at first the brain is only to be distinguished by its wider calibre.

While the changes in the epiblast are going on, the mesoblast also becomes differentiated. It forms at first a continuous

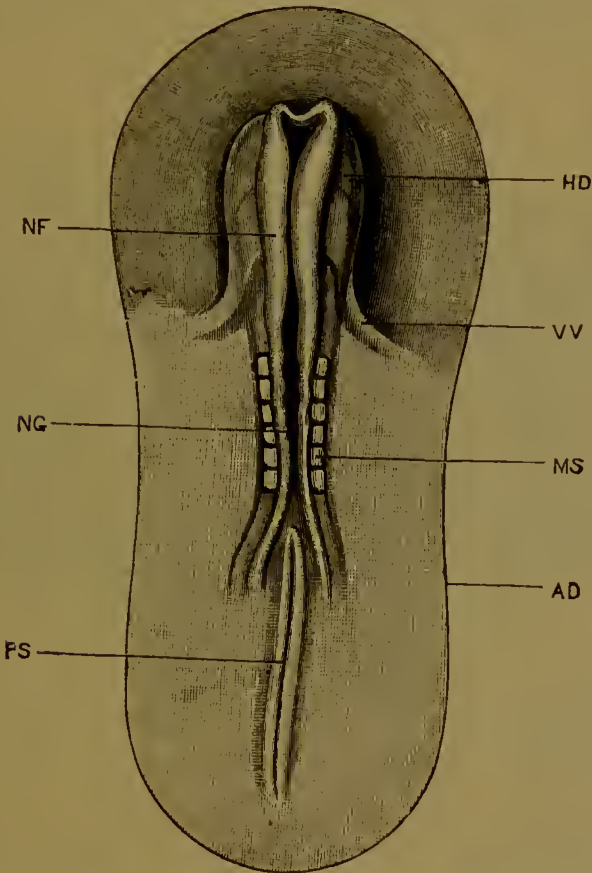

FIG. 68.—Surface view of embryo Chick at 24th hour. (From Marshall.)
HD, head; NF, neural fold; VV, vitelline vein; NG, neural groove; MS, proto-vertebræ; AD, margin of area pellucida; PS, primitive streak.

sheet with the threefold origin already spoken of. The first change to be noted is its splitting into a dorsal and a ventral layer, with the result that a cavity appears between them. This cavity is the **cœlom.** The upper layer of mesoblast is known as the **somatopleure**, the lower as **splanchnopleure.**

At the same time a split appears on each side of the body, parallel to the notochord, which separates the mesoblast into a vertebral and a lateral portion, while transverse clefts break up the vertebral portion of the mesoblast sheet into a series of squarish blocks, the **protovertebræ**, or, better, "**mesoblastic somites.**" At this stage, therefore, the embryo of the fowl is distinctly segmented, and, it will be observed, the portion of

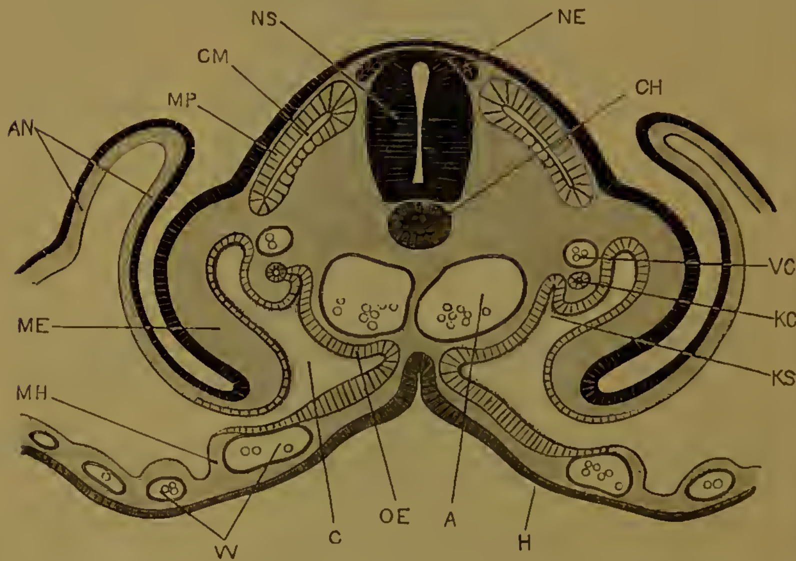

FIG. 69.—Transverse section of Chick at 48th hour. (From Marshall)

NE, spinal ganglion; NS, spinal chord; CH, notochord; MP, muscle space with contained cœlom (CM); VC, posterior cardinal vein; KC, Wolffian duct; KS, nephrostome; OE, genital epithelium; C, cœlom; A, aorta; AN, amnion; ME, somatopleure; MH, splanchnopleure; H, hypoblast; VV, vitelline vein.

the cœlom lying within the segmented portions of mesoblast is also segmented. There are, in fact, a series of cœlomic spaces as in the earthworm.

The fowl agrees with reptiles and all animals higher in the scale, to differ from the frog and other animals lying lower in the scale of vertebrated animals in the possession of an organ of protection for the embryo, which is known as the **amnion.** The first trace of this to appear is the head-fold (Fig. 69, AN), an upgrowth of epiblast first, but later lined with the somato pleuric mesoblast; then there is a corresponding tail-fold and two lateral folds—these meet and form a thin but double-layered sac, entirely covering the embryo above. The embryo sinks further into the yolk, which is being continually absorbed, and is, as stated, covered above by the amnion. Of this double-layered sac the part nearest to the embryo, which it closely invests, is known as the *true amnion ;* the outer layer becomes pressed against the egg-shell, and this portion is termed the *false amnion.* The space between these two layers is clearly cœlom.

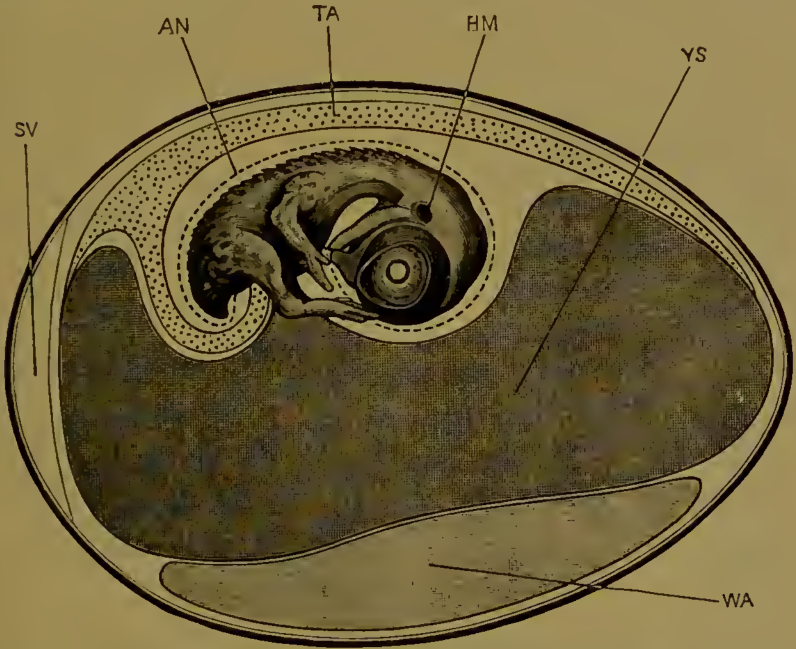

FIG. 70.—Embryo Chick at ninth day. (From Marshall.)
AN, true amnion ; TA, allantois ; HM, hyomandibular cleft ; YS, yolk-sac ; WA, white of the egg ; SV, air chamber.

Another embryonic organ, found in the frog as well as in the higher vertebrates, is the **allantois** (see Fig. 70, TA). The allantois is an outgrowth of the gut ; it is therefore lined with hypoblast, and covered externally by splanchnopleuric mesoblast. It grows into a large thin-walled sac, which comes into close contact with the shell, and serves as a respiratory organ for the growing embryo, absorbing, as it does, into its numerous blood capillaries the outside air. The allantois totally disappears in the adult fowl ; in the frog it is permanently retained as the bladder.

Certain Transitory Organs.—In the course of development of the fowl, as of other animals, various organs appear which develop up to a certain point and then disappear. These can be compared with organs found permanently in the lower types, and their transitory existence is regarded as tending towards the proof that the animals in which they are found in the rudimentary condition are descended from animals like those in which they are permanent structures.

Some of these structures have been already referred to, as was necessary in giving a general account of the early stages

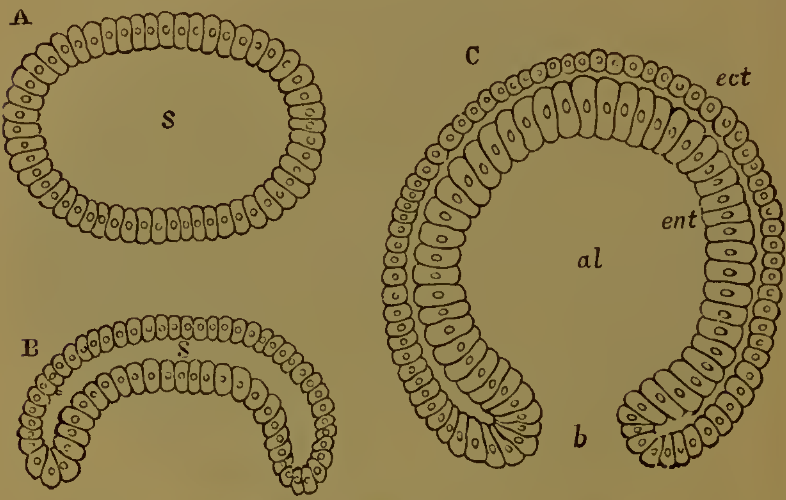

FIG. 71.—Formation of the gastrula of Amphioxus. (After Kowalevsky.)

A, wall of the ovum, composed of a single layer of cells; B, a stage in the process of gastrulation; C, completion of the process; S, original or segmentation cavity (blastocœl) of ovum; *al*, alimentary cavity of gastrula (archenteron); *ect*, outer layer of cells; *ent*, inner layer of cells; *b*, orifice, constituting the mouth (blastopore).

in the development. Thus the primitive streak is by most persons looked upon as the equivalent of the **blastopore** of other embryos, and as the equivalent of the mouth of cœlenterate creatures, such as *Hydra*. In many animals—for instance, in *Amphioxus*—the embryo, after a number of cell divisions, becomes a one-cell-walled hollow sac, the cavity being the **blastocœl**, equivalent to the similarly named cavity of the chick embryo. At one point this wall is thrust in, as is shown in the accompanying figures, thus producing a double-layered sac with a new central cavity and an aperture leading to the exterior, which is the aperture of invagination. If a hollow india-rubber ball be pressed in with the finger until the two opposite walls meet, some idea can be obtained of the **Gastrula**, as the embryo in this stage is termed. Now, in the fowl we have a groove formed, and with the formation of this groove coincides the formation of, at least, the greater part of the mesoblast. The mesoblast of *Amphioxus* is also established after the formation of the gastrula; but in *Amphioxus* the invagination of a layer of cells, at first external in position, is the way in which the hypoblast is formed, this layer being, in fact, the invaginated layer. In the fowl, as we have seen, the hypoblast is formed before the groove is produced. This is a difficulty in the way of considering the groove to be an abortive blastopore. The typical gastrula, such as that of *Amphioxus*, resembles *Hydra* in the number of points, which are—

1. It is two-layered.
2. The two layers are arranged in the form of a hollow sac.
3. The sac communicates with the exterior by an aperture, the mouth of the *Hydra* and the blastopore of the gastrula.

It is thought that, in the embryo at the gastrula stage we have a recapitulation of the *Hydra*-like form which was its remote ancestor.

Some other transitory organs will be more conveniently dealt with in the following general account of the development of the several systems. We may mention here, as being purely transitory organs, the *gill-clefts*. It will be remembered that the tadpole breathes by means of gills, which are vascular tufts arranged as fringes along the margins of certain clefts, which place the pharynx in communication with the outside world. In the embryo chick there are four of these clefts formed, which grow out from the hypoblast lining the pharynx, and come into contact with the epiblast, a perforation being formed at the points of contact. There are thus a series of apertures established. These, it seems necessary to suppose, are the exact equivalents of the gill-slits, though they never perform the part of respiratory organs; nor, indeed, do they appear to perform any function at all, which is a still further argument in favour of their being comparable to the gill-slits of the frog, since no use can be assigned to them, and so account for their presence.

The *notochord* is an organ of a similar character. In the Amphioxus the notochord is the only part of the skeleton to appear at all, and it persists throughout life. In the chick the notochord is replaced by (is *not* developed into) the backbone. This is an interesting case of a frequent phenomenon of what has been termed the "**Substitution of organs.**" Very often it happens that an organ is, as it were, manufactured out of another organ. An example of this is the formation of the sternum out of the ends of the fused ribs, or of the auditory passage out of the first gill-cleft. But sometimes a new organ, having a similar function to one already existing, is formed afresh in the same place. Thus the backbone is not a product of the notochord, but it appears at the same spot, and performs much the same function, strengthening the body in a longitudinal direction. In the one case—to use a homely simile—an old coat is cut down into a waistcoat; in the other, an entirely new coat of a different pattern is acquired.

Development of the Organs of the Body.

It will be more convenient to deal with the organs separately, instead of following a strictly chronological order and pursuing the course of development of all the systems together.

From the **epiblast** are formed the skin, *i.e.* the *epidermis;* the *central nervous system* (as already mentioned); the *stomodæum* and *proctodæum;* portions of the *eye* and of the *ear;* and the *olfactory organs.*

The *stomodæum* and the *proctodæum* are involutions of the epiblast to form the lining membrane of the first and last parts of the alimentary tract. The greater part of the lining epithelium of this tract is hypoblastic. But the mouth cavity is entirely epiblastic, while the posterior aperture is formed by a very short invagination of epiblastic cells.

It seems clear that all sense organs should be primitively external structures, therefore epiblastic. But in the vertebrate (and in some other animals too) the sense-organs are concealed within the body for protection. Nevertheless, their development shows that in all cases the sense-organs are epiblastic structures—that is, of course, the actual sensory parts of the organs; for, in the complicated sense-organs of the vertebrates, the eyes and ears, various accessory structures, which have merely a subsidiary function, also exist.

The *ear* first appears as an invagination of epiblast, which ultimately comes to form a closed sac. From this sac are formed the three semicircular canals and the rudimentary cochlea—in fact, all the essential parts of the ear. The mass of bone in which it is imbedded, and the small bones which serve as a conduit to the sound waves, are mesoblastic structures.

The *eye* is formed from three sources. There is, first of all, a pair of outgrowths from the brain in the shape of hollow vesicles. These become curved flattened plates, hollow within and connected with the brain by a hollow stalk. The plates, into which the ends of the primitive outgrowths of the brain expand, form the retina of the eye, while the stalk ends as the optic nerve. The *lens* of the eye is produced by a direct invagination from the exterior of the body. The rest of the eye structures are mesoblastic. It will thus be seen that the *retina*, which is the essential part of the eye, is epiblastic; not so directly, it is true, as in the case of the sensitive part of the ear. But, as the brain itself is formed by an involution of the epiblast, all structures derived from it must be also epiblastic.

The *olfactory organs* are also developed as epiblastic invaginations, but they have retained, to a greater degree, their primitive position. They still communicate with the exterior.

From the **hypoblast** is developed: the *epithelium* of the *digestive tract*, apart from that of the stomodæum and proctodæum just referred to; the *epithelium* of all the *glands* appended to the alimentary canal; the *liver* (including the *gall bladder*); the *pancreas;* the lining of the *lungs*, which are developed as outgrowths of the pharynx, and of the *air sacs*, which are but prolongations of the lungs;[1] the *notochord*.

The remaining organs of the body are derived from the **mesoblast.** It will be necessary to go more into detail into the description of the way in which some of these are developed.

The Vascular System.—The heart arises as two closely applied tubes, which soon fuse to become a single tube. The walls of this tube are muscular without, and derived from the mesoblast, and there is a lining of cells which have been stated to arise from the hypoblast. It is a remarkable fact that the heart begins to beat before the walls are differentiated into muscular tissue. Later on the heart becomes twisted into an S shape, and constrictions appear, marking it off into the several chambers of the adult heart.

The anterior end of the heart gives off a series of aortic arches, which, embracing the gut, unite upon its dorsal surface to form a dorsal aorta, running back along the median dorsal side of the gut. There are, altogether, five of these arches on each side, just as in the tadpole. But, though the chick thus resembles a tadpole or a fish, these aortic arches never send off ramifications in those types, since no traces of actual gills are developed. They simply lie between the gill clefts, and, indeed, are related to the heart on the one hand (a *tube*, be it remembered, at first) and to the dorsal aorta on the other, as are the so-called hearts of the earth-worm to the ventral blood-vessel and to the dorsal blood-vessel. The truncus arteriosus, as the anterior end of the heart is termed, is put into communication with the dorsally running aorta by these five pairs of circular vessels. Later in development the fish-like character of the aortic arches is lost. The middle parts of the first two arches disappear; the ventral parts persist as an artery, supplying the tongue of the adult, the lingual artery; the dorsal parts, as the carotids, which run up the neck to the brain. The other arches are partially or entirely lost, and the arterial system of the adult is arrived.

The dorsal aorta gives off two great branches. The first

[1] The muscular and connective tissue investments of these various organs are derived from the splanchnic mesoblast.

of these is the vitelline, which goes to the yolk sac; the second supplies the allantois, and is known as the allantoic.

The veins which return the blood to the heart are to begin with, and partly, arranged after the fashion of those of a fish. There are, as in those vertebrates, an anterior and a posterior pair of cardinal veins, which unite to form a pair of Cuvierian veins, into which blood is poured from the anterior and posterior regions of the body. Before these have appeared two large vitelline veins unite to enter the heart by a single

FIG. 72.—Surface view of Chick at end of third day, to illustrate vitelline veins. (From Marshall.)

SM, vitelline membrane; AD, area pellucida; AV, area vasentosa, with ramifying vitelline veins; AK, area space; EM, embryo.

trunk, and a little later a pair of allantoic veins join them. Still later a median vena cava posterior, the persistent vein of the posterior part of the body in the adult, opens through the same trunk, known as the meatus venosus. The anterior cardinals persist as the jugular veins, and the Cuvierian sinuses as the venæ cavæ anteriores.

The Excretory Organs.—In order to properly understand the excretory system, it will be necessary to supplement the account of the development of this system in the chick with some account of what occurs in the tadpole. In the latter the first part of the excretory system to appear is a rod of mesoblast, at first solid, afterwards hollow, which opens to the exterior *viâ* the cloaca, and in front communicates with the cœlom by three ciliated funnels, or *nephrostomes*. The exact way in which these are formed appears to be this: the rod is, as said, at first solid; it then becomes grooved along the inner surface, and ultimately the groove closes and shuts off a cavity, lying therefore within the rod—except at three points, which are the nephrostomes. The portions of the tube bearing the nephrostomes grow out into short tubes; these tubes become later branched and complicated. This structure is called the *head kidney*, and in the tadpole it plays the part of an excretory organ; it is later replaced by the mesonephros, and becomes degenerate, ultimately disappearing. The head kidney, or *pronephros*, as it is better to term it in correspondence with the mesonephros, is interesting as a relic in the frog, for in the marsipobranchs, or cyclostomata, it persists throughout life as a functional organ of excretion.

In the chick the pronephros is not only never developed as a functional organ of excretion, but it actually appears later than the mesonephros. As in the tadpole, the first part of the excretory system to be developed is the longitudinal duct, which corresponds to that of the tadpole. It acquires its lumen, however, by canalization, not by the closing of the lips of a groove—a difference, perhaps, of not great importance. It may be termed the *archinephric*, or segmental duct. Into this duct (there are, of course, two ducts, one on each side of the body) open a number of short tubules, the tubules of the *mesonephros* or *Wolffian body*. The anterior set of these tubules develops in two sections; a depression of the cœlom is formed, and within the mesoblast a coiled tube; the depression or nephrostome becomes continuous with the tube, and the latter with the longitudinal duct. This anterior set of tubules presently degenerates and disappears. The posterior set of tubules differs in having no nephrostomes.

Later, the rudiments of the *pronephros* put in an appearance. They are three depressions of the lining membrane of the cœlum (the number, it will be noted, corresponds to what is found in the frog), which become connected by a ridge of tissue. The anterior of the three funnels persists, and forms the mouth of the oviduct in the female; the ridge of tissue becomes the oviduct in the female, and grows back to open into the cloaca. It is present, but rudimentary, in the cock bird.

The mesonephros is the permanent excretory organ of the frog, but not of the fowl. Hence it is inaccurate to speak of both as kidney. In the fowl, on the fourth day, the archinephric duct gives off a diverticulum, from which is formed, by its elongation, the ureter of the adult. With this communicates a third set of tubules, also formed in the mesoblast, but without peritoneal openings. These tubules, with the duct, form the kidneys or *metanephros* of the adult.

The original duct, the archinephric duct, persists in the cock bird as the vas deferens; it acquires connection with the testis, and carries off the sperm. In the hen the mesonephric duct disappears, the Müllerian duct, as already stated, being the oviduct.

A tabular statement of the above facts may aid the memory.

TADPOLE.		CHICK.
Archinephric duct	=	Archinephric duct.
Functional pronephros of three tubes	=	Rudimentary pronephros, 3 funnels.
Mesonephric tubes	=	Mesonephric tubes.
Mesonephric duct (persistent pronephric duct, itself persistent archinephric duct, *minus* most anterior section), or Wolffian duct	=	Mesonephric (archinephric) or Wolffian duct.
Müllerian duct (independent (?) of pronephric duct)	=	Müllerian duct (a growth backwards of rudimentary pronephric duct).

FROG.		FOWL.
Excretory organ, mesonephros Ureter of male (also functioning as sperm duct) = mesonephric duct	=	Vas deferens (= mesonephric duct).
No structure present	=	Ureter.
Oviduct (Müllerian duct)	=	Oviduct minus funnel.
Funnel of oviduct	=	No structure present.
No structure present	=	Excretory organ, metanephros.

Before leaving the excretory organs, their correspondence in the embryo with the typical excretory organs of invertebrates must be pointed out. We have already seen that the nephridia are essentially glandular tubes which open on the one hand into the cœlom by a ciliated mouth, and on the other on to the exterior. That is precisely what we find with the pronephric tubes in the frog, and with the mesonephric tubes in both frog and fowl. But while the tubes of the earthworm open separately, those of the Vertebrata join to form a continuous duct, which, however, reaches the exterior by the cloaca itself, an invagination of the epiblast of the embryo. This fusion of separate nephridia does not, it is true, occur in the common earthworm; but Annelids are known in which several nephridia do unite to form a continuous longitudinal duct. Another apparent point of difference is that, while in the earthworm each segment of the body has but a single pair of nephridia, the mesonephric tubules, at any rate, are, for the most part, more numerous than the segments which they occupy; here, again, there is no real difference in the matter from segmented worms; for among the Annelids more than one form is known in which the nephridia show as little regard for the segmentation of the body as is evinced by the mesonephros.

CHAPTER XII.

MORPHOLOGY OF ORGANS.

In the foregoing pages the structure of a number of types of animals has been considered, and the development of one form has been dealt with. It may be useful to extract from that survey (adding something to the extract on the way) an account of the main facts in the structure of the higher animals from the point of view of the several organs and systems of organs. Hitherto we have characterized different animals by the structure of their different parts. We shall now examine *seriatim* the various organs themselves. The facts of Zoology, when treated in this way, are often spoken of as comparative anatomy or morphology. The term "Zoology" may be usefully retained for the consideration of animals in their entirety, their anatomy, mode of life, classification, and history, as indicated by fossil remains. The zoologist deals with the *animal* as an unit; the comparative anatomist with the *organ*. It is not intended, however, to insist upon any sharp line of division between these two aspects of the zoological side of biology; they obviously overlap.

In investigating the modifications of organs and systems of organs through the animal series, it is clearly requisite to be assured as to the exact equivalence of the organs under consideration. And this necessitates the use of terms with a definite meaning, such as is not always afforded by words in common use. It is not pedantic to speak of the jaws of an insect as mouth appendages. To term them "jaws" is to imply something in common with the jaws of a tiger. There is absolutely nothing in common structurally between the two organs, though they perform similar functions. The organs are, in fact, analogous, just as are (to use the most familiar instance of analogy) the wings of a butterfly and of a bird.

When organs correspond in structure and development, they are then said to be homologous. Thus there is no doubt that the heart of a man and of a shark are homologous structures.

But both these terms require further expansion and definition before they can become really useful. In extreme cases there can be no doubt as to which category a resemblance between two sets of organs can be referred. The leaves of a tree are in a sense the equivalents of the stomach and lungs of a man. In both organs are food assimilation and respiration carried on. But no one would assert that there is more than a not very strong analogy.

On the other hand, we may take such an example as the correspondence or non-correspondence between the heart of an anodon and that of a frog. Now, here we have two organs which play a like part—they are in each case the central organ of impulsion of the vascular system. Furthermore, there is this structural likeness between them, that both are divided into three chambers, of which two receive the blood coming from the veins, while the other, the ventricle, is concerned with the driving of the blood through the arteries. Finally, both organs lie in a pericardium. Yet no competent anatomist will dispute the assertion that these organs are not homologous, in spite of their almost detailed likeness. They are only analogous; but to an analogy of this kind it is useful to apply the term "homoplasy." This term signifies a similar moulding, an adaptation to similar needs. There are even more striking instances of, apparently, similar structures, which are yet different. It is not at all certain, for instance, that the two ventricles of the bird's heart are severally homologous with the two ventricles of a mammal's heart.

It would seem at first sight absurd to doubt that the four cavities of the heart of the higher vertebrates, mammals, and birds are really and truly homologous. But the doubts that exist are due to the great dissimilarities in other points of structure that exist between these two divisions of the group Vertebrata. So great are these, that no naturalist of to-day would accept for a moment the view that the mammals are highly developed birds, or that birds have been produced by a great change in the structure of any mammal-like form. Some even go so far as to believe that, while mammals are descended from some amphibian ancestor, the progenitors of birds were reptiles; but in any case it would probably be held by all that the two groups, if not derived from different classes of reptiles, diverged early and widely from the same type, which must in that case have been a lowly organized form, simple and not highly differentiated. The fact—the unfortunate fact—is that all questions of true homology depend upon what are, for the most part, speculations. It is unquestionably true to say that "to mix up ætiological speculations with morphological generalisations" induces confusion into morphology; but it is absolutely necessary to mix up the two, for all that. The test of true affinity must be common descent; and there are, and will be always, divergence of opinion about such matters. It has been, therefore, proposed, and with excellent reason, to change the term "homology" into "homogeny." "Homogeny" signifies community of origin; and structures which are clearly derived from each other, or from some common parent form, must be really homogenous. It will be clear to any one that the greatest difficulty of the morphologist is to distinguish between homogeny and homoplasy; in the case of the two ventricles of the bird's and mammal's heart impossible—at present, at least.

It must, therefore, be carefully borne in mind by the student who reads the following pages, that, while the facts are, it is hoped, correct, the comparisons may be by no means so correct.

The Body-wall (Epidermis, Dermis, and Muscular Layers).

In the earthworm the body-wall is divisible into the three layers which have been described; there is an epidermis outside, and this is followed by two muscular layers, an outer layer of circularly arranged fibres and an inner layer of longitudinal fibres. The epidermis is the epiblast of the embryo; the layers below are formed by the outer walls of mesoblastic blocks, the innermost layer being the cœlomic epithelium. The body-wall of the earthworm is sometimes spoken of as the dermo-muscular tube. In the crayfish the simple structure of the body-wall is more complicated. In the first place the empidermis, instead of secreting a simple transparent cuticle, produces a much thicker cuticle, which is for the most part calcified. The two muscular layers are no longer recognizable in their simplicity. Instead of two continuous sheets of muscle partly interrupted at the septa, which is found in the earthworm, the muscles of the crayfish are broken up into individual masses running in different directions, in which the regular arrangement is no longer visible. Furthermore, there is between the muscles and the epidermis a layer of connective tissue, the dermis, not represented in the earthworm.[1]

The immense thickness of the muscular layers has resulted in the nearly complete obliteration of the cœlom, as it has also in the cockroach, which from the present point of view is essentially like the crayfish. The same, too, is the case with the anodon and with the snail.

In the Vertebrata all the structures lying outside of the cœlom may be regarded as collectively equivalent to the dermo-muscular tube of the earthworm.

In both cases it is the product of the somatic mesoblast. But in the vertebrate the complication of this body-wall is much greater. The epidermis is thicker, and is among vertebrated animals modified in many different ways, some of which have been dealt with on p. 112, *et seq.* The same statement applies to the dermis. The muscular layers are divided up into separate muscles which have often characteristic arrangements serving to separate the great groups of vertebrates from each other. In the fishes, for example, there is a more regular and apparently primitive arrangement. The muscles are to some extent arranged in continuous sheets, only

[1] A dermis has been found in certain earthworms.

interrupted by fibrous partitions. In the higher vertebrates the muscular layers are more thoroughly split up into separate muscles. In vertebrates, finally, we get formed out of the mesoblast of the body-wall, as well as out of the splanchnopleuric mesoblast in the head region, the skeleton which has been already described in three vertebrate types, and need not be again described here.[1]

Nervous System.

The nervous system is entirely a product of the outer layer of the embryo, the epiblast. As a rule, however, much of it becomes removed deeper within the body, leaving only its terminal sensory endings in the outer layer of the body; and even these—as in the case of the retina of the eye, for instance—may also be removed from the surface. The nervous system of the higher animals consists of the central nervous system, which is a chain of ganglia or a cord containing numerous ganglion cells, and of a peripheral nervous system consisting of the nerves which arise from the central nervous system. The latter invariably end in sensory cells situated in the skin or elsewhere, in delicate sensory plexuses, or in muscle fibres. Hence the nerves of the peripheral nervous system may be distinguished into sensory and motor. In the simpler animals there is the rigid distinction referred to between the central and the peripheral nervous system. It is only the central nervous system where ganglionic cells occur. But in higher animals peripherally situated ganglia are to be found, such as the plexuses of cells and fibres connected with the alimentary system of vertebrates.

As would be imagined on *a priori* grounds, a general

[1] It must be remembered that the tissues formed between the epiblast and the hypoblast arise from at least two distinct sources, in the opinion of some embryologists; there are the mesoblastic somites (*protovertebræ*), (p. 132), and the *mesenchyme*, budded off as wandering cells from both hypoblast and epiblast. From the latter is formed *inter alia* a considerable portion of the skeletal elements. If this distinction can really be drawn, some of the above comparisons will fall to the ground.

diffused nervous system has preceded a differentiated central and peripheral nervous system. In *Hydra* there are nerve-cells scattered over the ectoderm, in association, chiefly at any rate, with the cnidoblasts. A diffused nervous system (associated, however, with a concentrated central nervous system) has survived in certain simply organized worms (the Nemertines) where there is a layer of nervous tissue completely surrounding the body. Even in the embryo frog there are more than traces of the same. The epiblast of the young embryo is divided into an outer layer, from which the future epidermis is to be derived, and a deeper layer from which the central nervous system is developed. This layer, however, is not found only where the central nervous system will be ultimately produced, but it is continuous right round the body, and is generally held to represent an archaic state of affairs, where a continuous nerve-sheath was the nervous system. Even in the same group to which *Hydra* belongs the commencement of a central nervous system is to be seen. Round the margin of the "umbrella" of Medusæ are special concentrations of nerve-cells, the forerunner of a central nervous system. In all the higher animals described in the present book a central nervous system is present; and in all of them it is removed from the epidermis, though—equally in all—it is developed from the epiblast of the embryo.

The central nervous system exists in these animals, it will be observed, in two rather different forms. In all the invertebrate types it consists of a supra-œsophageal ganglion or ganglia, connected with a subœsophageal pair of ganglia, or chain of ganglia by connectives that pass round the gullet. In the vertebrates, on the other hand, the central nervous system, consisting of the brain and spinal cord, is entirely dorsal in position, the alimentary tract being wholly ventral to it. There are, furthermore, these additional differences between the two types. In the vertebrates the central nervous system is not cut up into masses of nerve-cells connected by tracts of nerve-fibres, into ganglia and connectives; secondly, it encloses a central canal. The nervous stem of vertebrates is a tube of nervous matter. In the invertebrate the ventral and chief part of the nervous system consists of separated ganglia,[1] and is not a hollow structure.

There is, however, in spite of the important differences just enumerated, this in common between the two types of nervous system, that they both possess a mass of nerve-cells in the anterior end of the body above the mouth.

Thus the brain of the vertebrate, or at least a portion of it, seems to correspond to the supra-œsophageal ganglia of the invertebrate. That this point in common is important seems to be shown by the following considerations. In the lower worms, the Platyhelminthes, Nemertines, and even in a simple type of Annelid, *Æolosoma*, the central nervous system consists of the cerebral (supra-œsophageal) ganglia alone. Here we may possibly have the common starting-point of the vertebrate and invertebrate central nervous system. On this view it will be assumed that out of the nerves arising from the brain of these simple animals two ventral ones, in the case of the invertebrate, and two dorsal, in the case of the vertebrate, became respectively approximated, and formed the rest of the central nervous system. This is, of course, hypothesis; but, as a matter of fact, the first stage in proof of such an hypothesis has been discovered in the Nemertine worms; in some of these there is a dorsal, and in others a ventral, approximation of two especially stout nerves, arising from the brain. There are, however, other views attempting an explanation of the differences between the invertebrate and the vertebrate nervous systems. The matter does not at present admit of dogmatic teaching.

As to the invertebrate types, it is quite easy to see the likeness in their nervous systems. In *Lumbricus* there is a ganglionic swelling for every segment of the body, except the first one or two. But it seems as if a slight growing together of ganglia originally perfectly distinct had occurred in the first of the subœsophageal ganglia. The crayfish presents us with a further modification. In the first place, the ganglia are more

[1] In the earthworm the distinction between the ganglia and the connectives is not so marked as in the other types. There are some, but not so many, nerve-cells in the connectives.

clearly marked off from the connectives; in the second place, there is less correspondence between ganglia and segments than in the earthworm. It will be remembered, however, that the segmentation of the crayfish has not been so distinctly preserved as in the earthworm. The excretory organs have nearly, or perhaps quite, lost their segmented character; the same is the case with the thoracic and cephalic segments, etc. Hence it is not surprising to find that the nervous system has shared in this confusion of an originally simple metamerism. But it is worthy of note that the nervous system, inherited from much more remote ancestors than those which acquired the special characteristics of the Arthropoda, has retained so completely, on the whole, its regular metamerism.

The anodon at first sight differs from the types considered. The equal development of three triangularly situated pairs of ganglia tend to confuse the likeness to the worm and to the crustacean. The anodon, it must be borne in mind, is not a segmented animal; there is no trace of segmentation anywhere. Hence it could not be expected that the nervous system should be segmented, and it is not. But we have the supra-œsophageal ganglia connected by a circum-œsophageal commissure with a ventral pair, exactly as in *Lumbricus* and *Astacus*. There is, however, in accordance with the absence of segmentation, only one ventral pair. As for the parietovisceral, they are probably to be compared to the visceral nervous system of the two animals mentioned. The same observations apply to the snail.

Alimentary Canal.

The alimentary canal of *Hydra* is a blind tube, formed of the endoderm, and in close contact with the ectoderm, separated from it only by the structureless supporting lamella. In all the higher animals (with a few exceptions) there is an alimentary canal present, which is a tube running from end to end of the body, and usually opening at the posterior end by an anus as well as anteriorly by the mouth. The simplest expression, therefore, of a cœlomate animal is that of two tubes, one surrounding the other, enclosing between them a space, the cœlom.

The first appearance of the alimentary canal in all cœlomates is the archenteron. The archenteron is the equivalent of the gastric cavity of *Hydra*. But the alimentary canal of the adult cœlomate is not the exact equivalent of the gastric cavity of the hydra. For it has been found that the archenteron gives rise, without doubt, in a few animals, to pouches, from which the cœlom and its walls are formed; while in others, if this does not actually occur, it is in the opinion of many a modification of the same process of development which gives rise to the cœlom and the walls of mesoblast; and theory altogether apart, the hypoblast of the embryonic archenteron does give rise to, at any rate, a part of the mesoblast. Furthermore, in the cœlomate animals, two additional portions are added to the archenteron (*minus* the mesoblastic portion), viz. the stomodæum anteriorly and the proctodæum posteriorly, both of which are subsequent ingrowths of epiblast. These various layers of cells, however, only give rise to the actual lining epithelium of the alimentary tract and the lining epithelium of the glands, such as the liver, appended to it. The alimentary tract has, besides this epithelial lining, a wall composed of connective tissue and muscle. These outer layers are derived from the splanchnopleuric layer of the mesoblast. It is clear, therefore, that the alimentary tract of a cœlomate animal is not the precise homologue of the alimentary tract of *Hydra*.

There is no doubt that the alimentary tracts of all the higher animals are equivalent structures. They show, however, considerable variation in structure. The proportions of the stomadæum and proctodæum to the mesenteron vary greatly. The term "mesenteron," it should be remarked, applies to that portion of the gut whose epithelial lining is derived from the archenteron only. Thus in the crayfish all is stomodæum to the end of the stomach, while the proctodæum commences very shortly afterwards, the mesenteron being limited to a very short tract into which the liver opens. In the earthworm, on the other hand, the stomodæum ends with the pharynx,[1] and the proctodæum is an exceedingly short tract at the opposite end of the intestine.

Combined with these essential points of similarity in the alimentary tract of cœlomates are many points of difference. The canal itself is differently specialized in all the types considered in this volume, and the glands appended to it can only be said to generally correspond. It is impossible, for instance, to definitely compare the "liver" of *Astacus* with the liver of *Rana*.

Cœlom.

All the animals above the hydra which have been described in the foregoing pages, possess a cavity, or system of cavities, known as the cœlom. This space lies in the mesoblast, and is bounded by its own walls; it is not, that is to say, simply the interspace between various organs. The term "body-cavity" is sometimes applied to this system of spaces; but the term is ill-advised as applicable to any cavities in the body, as, for example, the quite spacious cavities in the cockroach, which are really a part of the hæmocœl. In representatives of three or four groups of animals it has been conclusively proved that the cœlom arises as a pair, or more than a pair, of diverticula of the embryonal gut (archenteron). These pouches grow out, and then meet to become fused, at least in part, and so surround the gut, whence they were derived. In the majority of animals, however, *e.g.* in the earthworm, the cœlom does not arise in this way.

It appears as a splitting of the mesoblast, the cells immediately abutting upon the cavity thus formed becoming the proper wall of the cœlom, the peritoneum. To a cœlom which arises in the former of these two ways the term "*enterocœl*" has been applied, and "*schizocœl*" to a cœlom arising in the second way. Thus *Amphioxus* possesses an enterocœl, *Lumbricus*, a schizocœl. The extent to which the cœlom is developed varies greatly among cœlomate animals. It is

[1] Possibly with the buccal cavity.

spacious in the earthworm and in the frog, much reduced in anodon and the snail, more reduced still in *Astacus*.

The cœlom can be distinguished from other spaces, such as the hæmocœl, by a number of characters. In the first place the mode of its development already sketched out; in the second place, when it is at all spacious it envelops more or fewer of

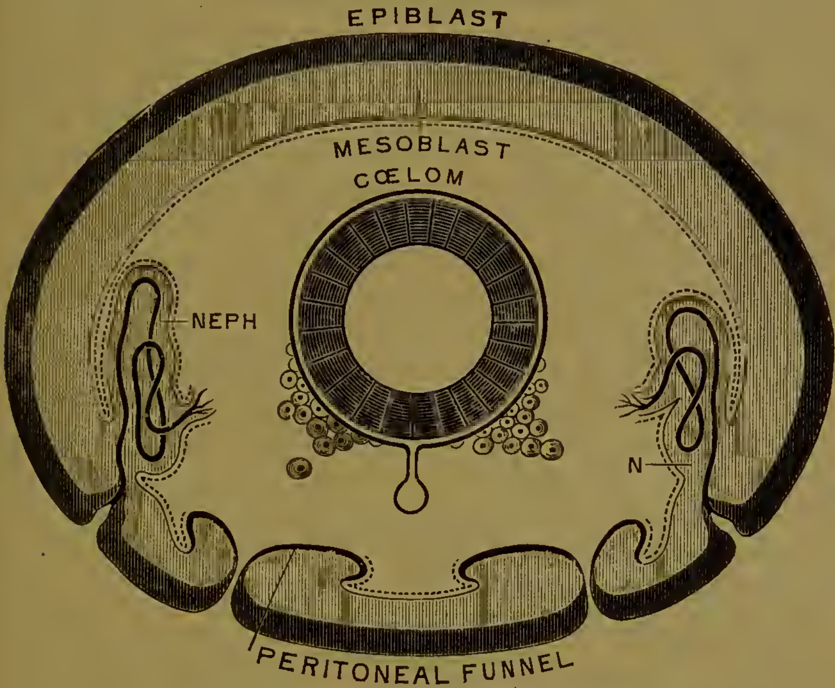

FIG. 73.—Diagrammatic transverse section of Earthworm, to illustrate some of the characters of the cœlom. (After Goodrich.)

N, NEPH, nephridia. Beneath the central gut are the generative cells budded off from peritoneum of septum (not shown). The dark line surrounding the gut is the splanchnopleuric peritoneum. Peritoneal funnel represents (diagrammatically) oviduct or sperm duct.

the organs of the body. In the earthworm all the organs of the body lie within the cœlom, or—to speak more accurately—they are invested by its walls. A glance at Fig. 153 will make this understood. The proper epithelium of the cœlom closely invests the intestine, nephridia, blood-vessels, etc. In anodon (Fig. 30, p. 65), where the cœlom is reduced to the pericardial cavity, the heart and a section of the intestine are enclosed by this cœlom in the same fashion. The cœlom of the crayfish (Fig. 25, p. 48), (the interior of the generative organs and the terminal vesicle of the green gland) is so reduced that all the organs of the body are excluded from it. The hæmocœl differs in these points from the cœlom. It is—at any rate, sometimes—formed at first of solid rods of mesoblast (p. 160), which melt down centrally, while the marginal cells form the walls. Finer vessels, the capillaries, have been shown in some animals to be produced by the direct canalization of rows of cells. Or, again, blood-vessels sometimes arise first as irregular chinks and lacunæ between the mesoblast cells. Blood-vessels are never formed either as archenteric diverticula or as a series of segmented cavities in the mesoblast. Nor do vascular spaces envelop other organs of the body, as does the cœlom typically. There appear to be exceptions to this statement, such as the so-called pericardium of *Astacus*, and the blood sinuses, which have been described as enveloping parts of the alimentary tract in certain worms. As to the crayfish, it has been already pointed out that we have probably to do with a number of veins which have fused together, and thus constitute an envelopment to the ventricle. In the worms referred to, it seems likely that the continuous sinus (if it really exists, a fact which has been questioned) is formed in a similar way by the coalescence of a plexus of blood capillaries.

The cœlom is further characterized by the fact that it communicates with the exterior, either temporarily (frog) or permanently (earthworm), by means of the excretory organs. It may also have other and more direct communications with the exterior, as in the case of the dorsal pores of the earthworm and the abdominal pores of the dogfish. In the case of the hæmocœl, it is doubtful whether communications with the outside world exist. Capillaries have been stated to open on to the exterior in certain earthworms and in various Amphibia; but the facts seem to require a renewed investigation. Curiously enough, nephridial funnels do sometimes appear to open into the hæmocœl. Apart from the Nemertine worms, about which there is not an universal consensus of opinion, there is the undoubted fact that in the frog the funnels of the mesonephros, detached from the rest of the organs, create a communication between the cœlom on the one hand and the renal veins on the other. The funnels are cœlomic, and a short tube leads into the renal veins. This, however, is not precisely comparable to the communication between cœlom and exterior in the typical fashion.

Finally, the generative products are local proliferations of the lining membrane of the cœlom; thus the gonads and the mouths of the nephridia and the gonad ducts are the only organs which can be said to lie actually inside the cœlom. It is this reason which leads to the inference that the cavity of the generative organ in *Astacus* is cœlom. These characters do not apply to the hæmocœl.

Excretory Organs.

It seems probable that, throughout the entire series of cœlomate animals, the preponderance of those organs which function as the eliminators of nitrogenous waste products are homologous organs. We shall take these organs first, and then discuss briefly certain excretory organs which are not so plainly derivatives of the same common ground-plan.

In the earthworm, it will be remembered, there are a series of paired nephridia; these are, apart from details, tubes of a glandular character, opening on the one hand into the cœlom by a ciliated funnel, and on the other hand by a muscular sac on to the exterior of the body. There is thus, by their means, a communication established between the cœlom and the outside world. The anodon is not a segmented animal. It possesses a single pair of excretory organs, the organs of Bojanus. These are essentially tubes communicating on the one hand with the cœlom (pericardium), and on the other with the exterior. As is the nephridium of *Lumbricus*, the organs of Bojanus of the mollusc are glandular tubes with a non-glandular terminal point. It is the prevalent opinion that they entirely correspond to a single pair of nephridia of the earthworm. So, too, with the single "kidney" of *Helix*.

In the frog the same style of excretory organ can still be traced. Not in the adult so clearly as in the tadpole. The details have been, to some extent, dealt with in the preceding pages upon embryology. The general facts that can be deduced from those details are that in the frog and other vertebrates there are a series of paired excretory tubules, opening into the cœlom, on the one hand, and on to the exterior, on the other, by means of a continuous longitudinal duct. These differences do not, however, invalidate the comparison, for there are worms in which some, at any rate, of the paired nephridia are connected by a longitudinal duct; while another fact about the segmental tubes of the Vertebrata—that they are not strictly metamerically arranged—is paralleled in other worms.

The essential likeness remains, that in vertebrates no less than in annelids, there are a series of tubes which open into the cœlom, on the one hand, and on to the exterior, on the other, and that these tubes in both cases are the organs for the excretion of waste nitrogenous products.

The excretory organs of *Astacus* and of *Periplaneta* are not so easily to be referred to the same series.

They are both animals with but little cœlom. The excretory organ of *Astacus* is so far like that of *Lumbricus* that it is a tube which is partly glandular, and which opens on to the exterior by a non-glandular portion. Of this non-glandular portion there is an appended sac—a diverticulum. In describing and figuring that organ attention has been directed to the fact that the glandular part of the organ terminates in a little oval sac—the terminal sac. It is held by some that this is a small pocket of cœlom; and in this case the excretory organ of *Astacus*—the green gland, as it is usually termed—will agree in essentials with a nephridium of *Lumbricus*. As for the large vesicle, which is a diverticulum of the duct of the nephridium, it presents no difficulties when compared with the nephridium of worms, for in many species of annelids the duct is provided with an appendix essentially similar.

There are, however, other arguments which may be advanced to show the correspondence of the green gland of *Astacus* with the nephridium of an earthworm. In the kidney of various vertebrated animals each separate tube, which development proves to be a nephridium, ends in a dilated sac, into which is thrust a coil of blood-vessels, the so-called glomerulus. This dilated sac, which is lined by an epithelium more flattened than that which lines the excretory tubules themselves, has been shown on very good grounds to be a cut-off bit of the cœlom itself. So that, in this case, we have an undoubted nephridium opening into a small sac, which is cœlomic, a state of affairs which we have *ex hypothesisi* in the crayfish. This, however, is rather an argument from analogy; it shows that it is, at any rate, reasonable to regard the terminal sac of the crayfish's excretory organ as a fragment of cœlom. There are stronger arguments still. *Peripatus* has been shown to be a very archaic form of arthropod animal. Among other characters which it possesses, which show affinities to the segmented worms, are a regular series of undoubted nephridia. These nephridia do not open into a wide space, like the cœlom of *Lumbricus*, but into terminal vesicles, which have been proved developmentally to be cœlomic pouches; these, though larger, are exceedingly like the terminal sac of the green gland of *Astacus*. Finally, in *Peripatus*, each nephridium opens on to the base of a limb as does the green gland of *Astacus*. The limbs correspond, and it seems likely, therefore, that the corresponding position of the nephridiopores has significance. In the event of its being shown that the terminal sac of the green gland of *Astacus* is not a cœlomic sac, there is still no decisive reason for removing the green glands from the category of nephridia; for in that case there will be no cœlom at all in the neighbourhood of the green gland, and if they are homologous with nephridia they cannot have an internal opening into the cœlom, for the very good reason that there is no cœlom to open into!

In the same way, from a comparison with other animals, some arguments can be put forward to show that the Malpighian tubes of the cockroach are referable to the same category of organs. At first sight they differ widely, for they are apparently appendages of the gut ending blindly, and comparable to the hepatic appendages, which no one has attempted to prove to be excretory organs comparable to nephridia. In the first place, however, the Malpighian tubes are appendages of the end gut, which is proctodæum, and therefore of epiblastic origin; morphologically, in fact, they open on to the exterior of the body, just as do the archinephric ducts of vertebrates, which debouch into the cloaca. As to the absence of any communication with the cœlom, there is no cœlom that has been described for them to open into. And since in certain worms, where there is a copious cœlom, the internal aperture of the nephridia is still sometimes obliterated (*Chætogaster*), it is not difficult to understand that this portion of the nephridium may have disappeared in *Periplaneta*. Moreover, in certain worms (the earthworm *Acanthodrilus*, certain Gephyreans) there are undoubted nephridia which do open into the cloaca, apart altogether from the vertebrates, which are probably further away from the tracheata. There is thus no insuperable objection to regarding the Malpighian tubes as modified nephridia. This, however, is not the same thing as saying definitely that they are referable to the same category.

Gonads and Genital Ducts.

In most Cœlomata genital ducts or gonad ducts exist. In some of the more lowly organized forms the genital products, when ripe, escape by the mere rupture of the body-wall; such is the case, for instance, in certain simply organized worms, such as *Polygordius*. In other animals the genital products escape through definite pores, which place the cœlom in which they are formed in communication with the exterior. The cyclostomatous fishes are an instance to the point; so, too, certain lowly organized worms, such as *Æolosoma*. It seems, however, to be not settled in these cases whether the pores are not the last remains of definite ducts. They certainly appear to be so in such animals as the worm *Enchytræus*.

In those animals which have separate genital ducts there are anatomically two kinds, which seem to be more distinct than they are. In such cases as the oviducts of the frog and of the earthworm, the ducts are altogether independent of the gonads, whose products they convey to the exterior. The mouths of the ducts are at some distance from the gonads, and not nearly even in contact with them. In the other type, exemplified by the male ducts of the frog, the ducts of both sexes in the *Anodon*, *Periplaneta*, and *Astacus*, the ducts have the appearance of simple prolongations of the gonads. It is probable, however, that this difference is not a fundamental one. A consideration of the male ducts and the testes of the earthworm gives the clue to the difference; it offers an intermediate condition between the gonads independent of the duct and the gonads continuous with their duct. In the earthworm the testes are two pairs of bodies perfectly independent of the ducts in the young; later on certain sacs, the sperm sacs, are formed, which envelop both testes and the funnels of the sperm ducts. Thus both are enclosed in a common cœlomic sac, and appear to be continuous structures, an appearance which a careful dissection shows not to be a reality. Now, in those animals with continuous genital organs and genital ducts, there is, for the most part, a reduced cœlom. This is so with *Anodon*, *Helix*, *Astacus*, and *Periplaneta*. In those animals it is believed that the interior of the generative gland is, as already stated, the remains of a part of the cœlom. Hence the apparent continuity of the duct with the gonad is merely an exaggeration of the state of affairs which is found in the case of the male ducts and the testes of the earthworm; the common wall enveloping gonad and duct is the wall of the cœlom. As to the male ducts of the frog and other Vertebrata, the continuity is arrived at by secondary growths putting into connection the originally distinct gonads and ducts.

The gonad ducts themselves are usually held to have some relation to nephridia. This connection is emphasized by the usual way in which both systems of organs are often treated in the vertebrates under the general term of the genito-urinary organs. As to the vertebrates, it will be clear from what has been written above concerning the development of the genito-urinary organs, that there is the most intimate connection between the two. Ducts originally part of the excretory system (*e.g.* pronephric duct) serve in the adult as gonad ducts. It cannot, however, be argued on *à priori* grounds that this is necessarily the case with other animals. And yet there are certain facts which seem to indicate that, generally, there is a connection between nephridia and gonad ducts. In the earthworm there are certain obvious similarities which cannot be passed over. Genital ducts, as well as nephridia, open by open ciliated mouths into the cœlom, and by a pore on to the exterior. In the case of the oviducts the whole tube occupies two segments, perforating the septum as does a nephridium. The male ducts, it is true, are so far unlike nephridia that they traverse several segments on their way to the exterior; but there are many worms belonging to the same large group as that which contain the earthworm in which the male ducts also occupy but two segments. There are some other facts which point in the same direction, but we shall not enter into a description of them here, as they would be strengthened by further investigation. With regard to the anodon, the genital ducts are not only distinct from the nephridia, but they open on to the exterior by a separate pore; but among the Lamellibranchiate Mollusca there are forms in which the genital duct opens by the same pore, and others in which the two ducts are a common tube for some distance; this looks much as if the gonad duct is really a part of the nephridium split off. The genital ducts of the crayfish have this fact in common with the green glands (hypothetically, at any rate, nephridia), that they open on to the thoracic appendages at a point precisely corresponding with the place of opening upon the antennæ of the green glands. There is a suggestion here of a series of metamerically arranged nephridia, of which only one—the green gland—has retained its excretory function, while two others remain, one in each sex, as either oviduct or sperm duct.

Vascular System.

The vascular system is not found in the simpler cœlomate animals. It consists essentially of a system of spaces, containing a fluid, and excavated in the mesoblast. This system is perfectly independent of the cœlom, and generally this independence is shown by the different character of the enclosed fluids. Thus, in the earthworm the blood is red, with a few corpuscles; in the case of the cœlomic fluid we have numerous and large corpuscles floating in a colourless fluid. In order to emphasize its distinctness the term "hæmocœl" is often applied to the vascular system in its entirety. But though the hæmocœl is distinct from the

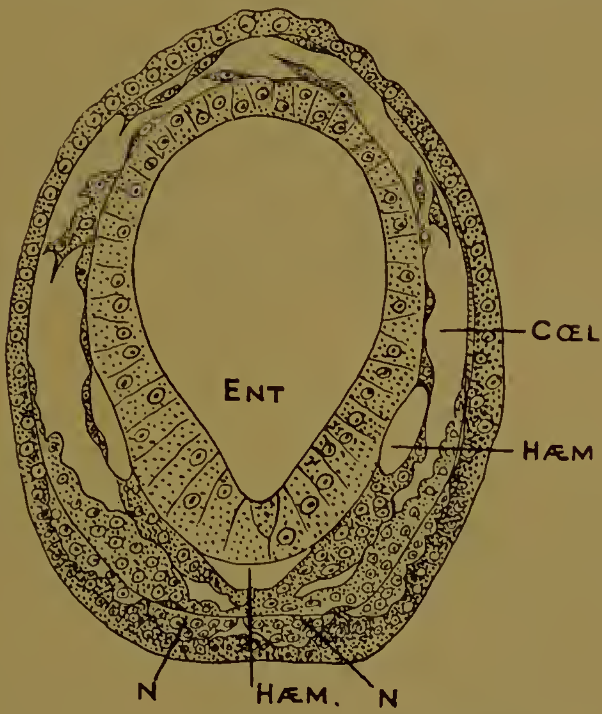

FIG. 74.—Transverse section of an embryo Earthworm, to illustrate independence of cœlom and hæmocœl. (After Wilson.)

ENT, gut; CŒL, cœlom; HÆM, hæmocœl; N, nerve-cord.

cœlom in its development, there is sometimes a connection between the two. Thus, in the vertebrates the lymphatic system opens, on the one hand, into the cœlom, and, on the other, into the hæmocœl. In simpler animals the channels of the vascular system have not always proper walls. In the majority, however, they have, and then tend to become tubes of regular calibre. A larger or smaller part of these tubes may develop muscles in the walls, which then contract, driving the contained blood from place to place. In the earthworm the dorsal vessel and the lateral hearts are thus contractile, and play the part of the heart of higher types. The trunks of the vascular system are usually arranged in a longitudinal direction, the trunks being connected by transversely arranged vessels. Such an arrangement is well seen in the earthworm. In this animal it clearly shares the general segmentation of the body. In the crayfish, which is also a segmented animal, but one in which the segmentation of the internal organs is commencing to be obscured, the metameric arrangement of the vascular

FIG. 75.—Isolated capillary network formed by the junction of several hollowed-out cells. (From Quain's "Anatomy.")

c, a hollow cell the cavity of which does not yet communicate with the network; *p*, *p*, pointed cell-processes, extending in different directions for union with neighbouring capillaries.

system is still obvious, but not so clear as in the earthworm. There is no longer a metamerism of the vascular system in the anodon. In the vertebrates the metamerism is plainer in the embryo (aortic arches) of the higher types.

The central organ of impulsion of the vascular system—the heart—is to be regarded as a local modification of one of the chief trunks of the system. The simplest form of heart that exists is probably that which occurs in an earthworm (*Microchæta*); it is simply a local thickening of the dorsal vessel, which has here more highly developed muscular walls, and is thus possibly more powerfully contractile than the rest of the dorsal vessel. From this it is not difficult to derive the heart of *Astacus*. The heart in this animal is continued in front into the ophthalmic artery, and behind into the abdominal; it has thus quite the appearance of a local thickening of a continuous dorsal trunk, comparable to the dorsal vessel on the earthworm. But the heart of the crayfish is complicated by the presence of an auricle, completely surrounding it, into which open the branchial veins. These may possibly be regarded as the equivalents of the circum-œsophageal "hearts" of the earthworm, like which, they show distinct traces of metamerism. A further stage is seen in anodon. The ventricle of the heart can be looked upon as a thickening of a dorsal vessel, the arteries behind and before which arise from it representing again a non-modified part of an originally simple dorsal vessel. The two auricles opening into the single ventricle would, in that case, perhaps, be comparable to a single pair of the circum-œsophageal vessels of the earthworm, the segmentation of this part of the vascular system being entirely lost, as is that of all the other organs of the body.

The same remarks apply to the snail; but here not only is the segmentation lost, but bilateral symmetry also.

These invertebrate types differ from the vertebrate in that the heart is dorsal. It is an important morphological difference that in the vertebrate the heart is ventral. Thus, it is probable that the heart in the two series of types is not strictly comparable. Otherwise the concentrated heart of the vertebrate, with its three to four separated cavities, is derivable again from a specialized part of a longitudinal ventral vessel. The heart at first arises as a simple tube, which afterwards becomes twisted. The auricles, therefore, of the frog's heart, derived from the division of an, at first single, auricle, cannot be directly compared with the auricles of anodon; for in the frog they are morphologically the posterior part of the heart-tube, which by subsequent twisting come to lie in front of the ventricle. Even in the vertebrate it is possible that the prevalent circular vessels of lower types are to be recognized in the aortic arches, which are essentially, in the embryo chick, communications between a dorsal and a ventral vessel.

When a definite heart is established, it is customary to speak of arteries and veins. To those trunks which convey blood away from the heart the term "artery" is applied; veins are the trunks which convey blood to the heart. Both vessels communicate peripherally, usually by means of finer tubes (the capillaries), in which region the distinction between artery and vein is extinguished.

Respiratory Organs.

In animals with a delicate body-wall it frequently happens that there are no special organs of respiration at all. The thinness of the body-wall permits an æration of the blood capillaries which it contains. This is the case with the earthworm, where the entire surface of the body performs the office of a lung, or branchia. In animals with a thicker body-wall, where such an æration cannot take place, special organs occur which are devoted to respiration.

While there are certain grounds for believing that the organs for the secretion of nitrogenous waste are homologous throughout the animal series, this is by no means the case with the organs of respiration. In the animals whose anatomy has been described in the foregoing pages four types of respiratory organs are met.

1. *Branchiæ.*—These are outgrowths of the epidermis, with some of the underlying mesoblastic structures included. In the latter course the blood-vessels, which come to be separated from the oxygen-containing medium by a thin epidermis only. Such branchiæ, or gills, are commonly arborescent, in order to increase as much as possible, without an undue increase of the length of the organ, the respiratory surface. The branchiæ of the crayfish and of anodon, and the external gills of the young tadpole, belong to this category.[1]

2. *Tracheæ.*—The tracheæ of the cockroach are respiratory

[1] A variation of this form of respiratory organ is found in the echinoderms, and even in a few annelids (*Branchiura*), in which the branchia contains a prolongation of the cœlom.

organs which fit in with a terrestrial life, just as the branchiæ—delicate structures which would dry up and become inefficient if exposed to dry air—are suited to the aquatic life. The tracheæ are essentially tubes which open on to the exterior by the stigmata, and at the other end branch repeatedly and ramify in the body, carrying the air to the tissues of the most distant organs. The tracheæ, therefore, are not respiratory organs in the sense that branchiæ are. The latter are the organs where—and where only (in the crayfish)—respiration takes place; the tracheæ are merely conduits for the air, each organ absorbing from them its own oxygen, and giving up its carbonic acid.[1]

3. *The Gills of Fishes and Tadpoles.*—A third form of respiratory organ characterizes vertebrates. It is one of the most important definitions of this group that, either temporarily or permanently, there are a series of slits putting the pharynx into communication with the outside world. These slits, temporary in Amphibia and all vertebrates lying above them in the series, are permanent in fishes, and there become fringed with vascular tufts, and perform the office of gills. The water taken in at the mouth is passed through these slits, and as it passes the delicate epidermis covering the vascular tufts gives up its oxygen to the contained blood. This same process of respiration goes on in the tadpole.

4. *Lungs of Vertebrates.*—In the adult frog, and in all vertebrates lying above it, respiration is effected by a pair of sacs, outgrowths of the pharynx, the lungs.

It has been attempted to be shown that these sacs are really homologous with a pair of gill-slits. The latter originate as outpushings of the pharynx to which inpushings of the epidermis correspond. The lungs, it is suggested, are the outpushings only, which thus never acquire a communication with the outside world.

The diversity of respiratory organs contrasts, as has been pointed out, with the uniformity of the excretory organs. It is

[1] In some aquatic insects there is a curious modification of the tracheal system. The tracheæ, unprovided with an external orifice, lie in outgrowths of the body-wall, which are perfectly comparable to branchiæ.

interesting to inquire why this is so. Possibly it has something to do with the absence of any necessity for special organs of respiration in thin-walled animals.

The secretion of nitrogenous waste matters is (largely, at any rate) an elaborate process of chemical manufacture, which requires a special organ for the purpose. Once acquired, there is no *à priori* reason why a different organ should be formed for the same purpose. On the other hand, skin respiration must be regarded as a primitive state of affairs, and special respiratory organs were only needed as the organisms became bulkier and consequently with thicker integuments. Hence respiratory organs were produced at various periods and separately in many groups of animals. Therefore there is no reason why they should be of the same kind.

In this connection it is interesting to note that many animals with special organs of respiration still continue to breathe partly by their skin. This is so with anodon; and it is well known that the skin of the frog is respiratory. In *Helix* the mantle-fold has become so vascular, and so well adapted for respiratory purposes, that the branchiæ—present in allied forms—have totally disappeared.

CHAPTER XIII.

THE MORPHOLOGY OF TISSUES (HISTOLOGY).

The bodies of animals can be not only analyzed into organs, but also into tissues and cells. At present the cell is the ultimate unit of structure. That portion of morphology which deals with the microscopic structure of animals, with the forms and arrangements of the cells and of the tissues, is usually called *Histology.*

It has been already pointed out that all animals are composed of one cell or of many. Among multicellular animals there is always some differentiation of the cells. Thus in the hydra the cells of the endoderm differ in their characters from the cells of the ectoderm. The latter, again, are to be distinguished into the larger muscular cells, and the smaller interstitial cells; the interstitial cells, again, are differentiated into cnidoblasts, nerve-cells, etc. But the entire animal is quite obviously composed throughout of cells, which are fundamentally very similar. If the section of *Hydra*, on p. 15, be compared with the figure of a transverse section through the body-wall of an earthworm on p. 22, the cellular constitution of the latter will not be quite so obvious. That the epidermis is made up of definite cells of two kinds is as clear as possible; but underneath the epidermis are two layers of muscles, which are composed of fibres running in two directions, and imbedded in a granular substance, through which are scattered nuclei. Nevertheless, these layers are really composed of cells.

Fig. 76 represents a section through the body-wall of an embryo earthworm. It is composed of the same three layers as those which are shown in the last figure described. But the inner layer of muscles is clearly a cellular layer; it is made up of large cells, in the interior of which fibres are being formed. These fibres are seen cut across, so that they, of course, appear as circles. So that what we have in the body-wall of the adult worm is a group of cells of which the boundary lines have disappeared, and of which the protoplasm has been largely converted into long fibres of contractile substance. The nuclei remain unaltered to tell the story of the metamorphosis of these cells. It may be remarked that, though the figure does not

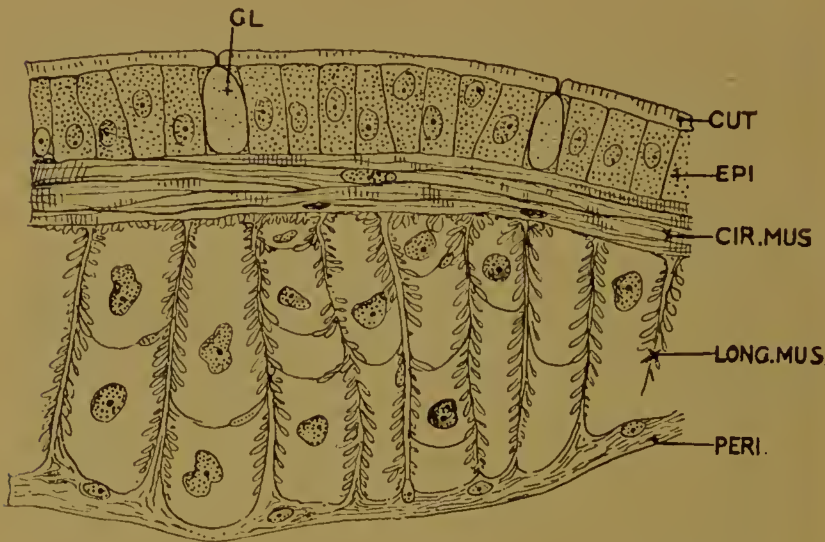

FIG. 76.—Section through body-wall of embryo Earthworm. (From Vejdovsky.) CUT, cuticle; EPI, epidermis; GL, gland-cell; CIR.MUS, circular muscles; LONG.MUS, longitudinal muscles; PERI, peritoneum.

show it, the circular layer of muscles at an earlier stage is developed in precisely the same fashion.

It is true of the higher animals generally that their tissues, in many cases, depart widely from the typical cellular form; but it is equally true that those tissues are invariably composed of cells. The most important generalization of histology is that the bodies of all animals and plants are composed of cells.

We have already several times used the term "tissue." It is now requisite to define this term as used in histology.

A tissue is a cell aggregate—a group of cells—similar in character, with a function corresponding to their character.

There are four main classes of tissues among animals; but these are again subdivisible. To use a metaphor borrowed from systematic zoology, there are four genera of tissues, and each contains a number of more or less closely allied species.

The four genera of tissues are (1) epithelial, (2) muscular, (3) nervous, and (4) connective.

We cannot here enter into anything like a full account of these several tissues, or even their principal modifications; these matters are more suitably treated of in detail in a physiological handbook, and will be so treated in a later volume of this series.

But a few general facts and conclusions may be suitably introduced into a handbook of zoology.

The *epithelial tissues* may be exemplified by the epidermis of the earthworm figured upon p. 168. Similar tissues are the epidermis of the frog, the cells which line the gut of the same and other animals, the tissues which form the tubules of the kidney, etc. In all these cases the tissue is composed of groups or layers of cells similar to each other, which have preserved the typical cellular form. In the simplest animals, such as *Hydra*, all the tissues are of this kind.

The *muscular tissues* are characterized by the fact that a large portion of the cells of which they are composed have been metamorphosed into fibres of a contractile substance. All protoplasm is contractile, as is shown by the movements of an *amœba* and by the circulation of the protoplasm in a vegetable cell. But in these cases there is no line to be drawn between those portions (of the ectoplasm, at least) which are especially contractile and those which are less so. In the *Vorticella*, on the other hand, there is a definite layer of the ectoplasm —the myophan layer—in which contractility principally resides. In the ectoderm of the multicellular *Hydra*, special cells are set apart to perform the part of contractility; but it will be observed that these cells have not lost their typically cellular character. A process, or two processes, have grown out from their under surface which are not, or are hardly, distinguishable from the protoplasm of the rest of the cell; these are the muscular processes of those cells. In animals belonging to the same great division as that which contains the hydra, we get a further evolution of the muscle-cell. In such cases (see Fig. 77) the fibre is much more important than the cell of which it is a formation. Nevertheless, the cellular constitution of a muscle-fibre is plainly evident.

In the higher animals, as has already been pointed out in the case of the earthworm, the cellular constitution of the muscle-fibres is not always evident. It *is*, however, during the course of the development of the fibres. Fig. 78, for example, which represents a muscle-fibre of an embryo sheep, is absolutely like the muscle-fibre of an adult medusa. The

FIG 77.—Muscle-cells of Cœlenterate. (From Claus-Sedgwick's "Zoology.")

FIG. 78.—Developing muscular fibres of fœtal Sheep. Highly magnified. (After Wilson Fox, from Quain's "Anatomy.")

cell here is partly metamorphosed into a fibre. A bundle of the fibres closely associated together with a more complete disappearance of the original protoplasm of the cell is a muscle-bundle. In the case of the medusa, and in others, each cell gives rise to a single fibre only; but in the earthworm, as already mentioned, several fibres appear in the interior of each cell. But this is not a difference of importance; neither is the distinction between the striate fibres of all vertebrates and some invertebrates and the smooth muscular fibres of vertebrates and invertebrates a matter of fundamental distinction. The striated fibre consists of muscular substance.

which is arranged in the form of alternating light and dark bands, concerning the physical explanation of which there is much divergent opinion. These cross striæ are not visible in the plain or smooth fibres. The striated fibres of vertebrates are developed in the way shown in Fig. 78, the plain fibres, on the other hand, are simply elongated cells (see Fig. 79), in which all but a small portion near the centrally placed nucleus has become muscle substance. The smooth muscle-fibre is more clearly cellular in its adult condition than is the striated fibre. But though there is this difference in the cases selected, it is not of universal applicability, for in the earthworm we have smooth fibres which are developed as are the striated fibres of the vertebrate, the nucleus remaining outside of the fibre; while, on the other hand, there are striated fibres where the nucleus remains, as it does in the plain fibre of the vertebrate, within.

The *nervous tissues* are essentially composed of cells which have, as a rule, many and much-branched processes. The processes are the nerve-fibres which seem to be always outgrowths of the nerve-cells.

The *connective tissues* do not really form so clearly definable an assemblage as do those already treated of. Their general characters are that they consist of

Fig. 79.—Muscular fibre-cells from the muscular coat of the small intestine. Highly magnified. (After Schäfer, from Quain's "Anatomy.")

Fig. 80.—Tendon of Mouse's tail, stained with logwood; showing chains of cells between the tendon-bundles. 175 diameters. (After Shäfer, from Quain's "Anatomy.")

aggregates of cells in which the typical cellular character is largely lost through the conversion of a larger or smaller portion of the cells into a connecting substance, which may be of a transparent structureless appearance, or may be definitely fibrillar. The accompanying figure (Fig. 80) will illustrate one form of connective tissue exemplifying the fibrillar change, while Fig. 81 of hyaline cartilage will exemplify the first-mentioned type

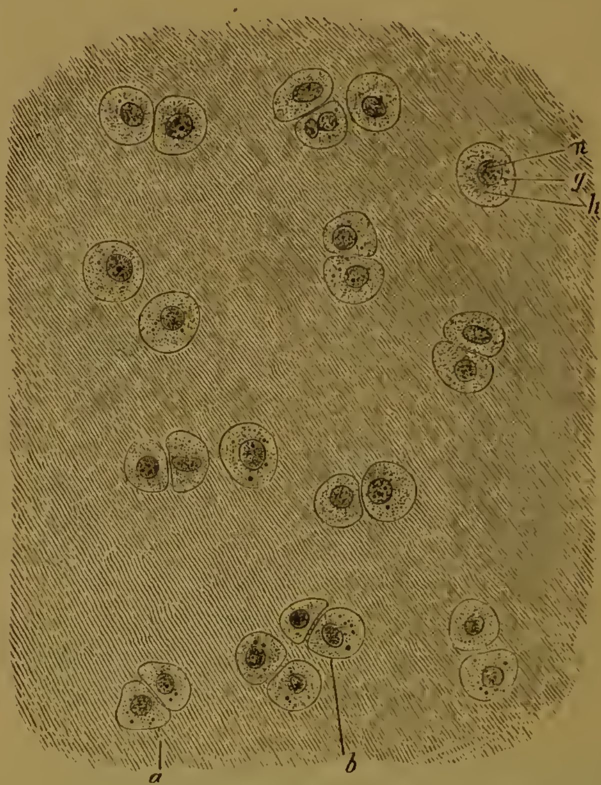

FIG. 81.—Articular cartilage from head of metatarsal bone of Man (osmic acid preparation). The cell-bodies entirely fill the spaces in the matrix. 340 diameters. (After Shäfer, from Quain's "Anatomy.")

a, group of two cells; *b*, group of four cells; *h*, protoplasm of cell, with *g*, fatty granules; *n*, nucleus.

of modification. These tissues are always skeletal or protective. Thus bone and cartilage are skeletal tissues, while the layers of more delicate connective tissue, which evolve and permeate the different organs, are rather protective in function.

CHAPTER XIV.

CLASSIFICATION. THE DIFFERENCES BETWEEN PLANTS AND ANIMALS.

In a footnote to p. 1, it was promised to define what naturalists mean by the terms "genus" and "species." A species is a group of animals (or plants) of which the individuals agree in all but perhaps the very minutest details. This may be illustrated by common examples among the earthworms. Under stones and in damp places there is frequently to be met with an earthworm of a greenish colour and small size; it is commonly coiled into a crescent, and is somewhat sluggish in habit. On wet mornings, and in dryer weather by digging, a different form, of a greyish blue colour and more active habits, is to be found. The green species is known as *Allolobophora chlorotica*, the bluish worm as *Allolobophora cyanea.* On examination the green species will be found to have a clitellum occupying segments 30–37, sometimes including also the twenty-ninth; it has, moreover, three pairs of spermathecæ. The bluish form has a clitellum occupying only segments 29–34, and there are but two pairs of spermathecæ. Wherever we find an earthworm with the characters just given, it will be found to agree in all other particulars with other individuals presenting those same characters. Some examples of *A. chlorotica* do not show the usually characteristic green colour, and in some the clitellum begins a segment earlier than is usual for the species, *i.e.* segment 29. Some naturalists separate off those individuals which show these minute differences from the typical form into a variety or sub-species; but it is simplest merely to speak of such examples as variations from the type form. It is not possible for the careful observer to confound these two species of *Allolobophora* with each other or with any other earthworms. The two forms have a real existence as definable animals. We may go a step further and complete the definition of the species by stating that they both inhabit the greater part of Europe. The area inhabited by a species is just as much a part of its definition as is its colour, or shape, or internal structure.

Now, each of these worms has two names—*Allolobophora* and *chlorotica*, *Allolobophora* and *cyanea*. The second name is the *specific* name, the first the *generic*. The two species, and about sixty others, agree with each other to form a larger assemblage of earthworms than a species, to which the term "genus" is applied. All the species of *Allolobophora* agree in having the male pores upon the fifteenth segment, in which they contrast with another but smaller assemblage of worms in which the same pores are situated upon the thirteenth segment. This distinction is held by systematists to be of more importance than variations in the number of spermathecæ, position of clitellum, etc.; and, accordingly, the worms with male pores upon the thirteenth segment are separated off into a genus, *Allurus*. But while there can be no difference of opinion about the existence of a given species—save as to the use of such terms of description as "sub-species" and "variety"—a genus has no such definite existence. The animal world consists of so many species which are grouped into fewer genera. The aim in the formation of genera is to indicate real affinities, genuine blood relationship. Such relationships, however, can only be surmised, they cannot be proved; hence notions as to what constitutes a genus must and do vary with the individual naturalist, for the "personal equation" comes into play.

Genera, again, are grouped into larger divisions, termed "families." The same remark that was made about genera may be also made about families. One naturalist will decline to regard as more than a genus what another will consider entitled to family rank. But both believed, of course, that the family consists of genera which are more nearly allied to each other than any one of them is to a genus belonging to another family. All earthworms, for instance, which have a clitellum beginning as far back as at least the twenty-second segment, which possess spermathecæ without diverticula, in which the gizzard lies immediately in front of the intestine, and which never have more than eight setæ to each segment of the body, are grouped together in the family Lumbricidæ. On the other hand in the East, and in Australia, are worms met with which agree in having a large number of—sometimes as many as seventy or more—setæ in each segment, the clitellum begins as early as the thirteenth or fourteenth segment, the spermathecæ always have one or more accessory pouchlets, and the gizzard is separated from the intestine by a stretch of œsophagus; these are ranged into a family, Perichætidæ. Families, again, are combined to form orders; the earthworm belongs to the order Oligochæta. This order contrasts with the order Polychæta, which includes the marine worms, such as the lugworm, by possessing no locomotorial processes of the body, containing closely associated bundles of setæ, and in a number of characters. Broader divisions still reduce the animal world to a few classes, until ultimately animals can be grouped into two great divisions, the Protozoa and the Metazoa, which will be defined and contrasted later.

The classification of the animal world adopted in this book will be found to differ from many schemes of classification in vogue. This is because of the uncertainty of our knowledge, and the consequent variability of opinions. The boundaries of many genera, families, etc., are indistinct; a student of zoology soon becomes familiar with what are known as intermediate types. The Dipnoan fishes, for example, have retained many fishlike characters, while they have adopted in addition to these amphibian characters. There are, in fact, in nature no sharply marked lines of division; and, if there appear to be, it is on account of defective knowledge. Until a year ago it was possible to distinguish, by a number of important characters, the leeches from the earthworms; but, in 1896, the characters of a remarkable leech, *Acanthobdella*, were more fully made known. This animal, a leech, in many of its peculiarities has setæ, like those of earthworms, and its body-cavity is divided into a regular series of chambers, a feature which formerly absolutely separated all Oligchæta from all Hirudinea. The first proper description of *Peripatus* broke down a number of the boundaries which kept the annelids apart from the arthropods; and many similar instances might be cited. Facts like these—and they are multiplying every day—show that classification, if possible practically, is theoretically impossible; the paradox, in fact, is true, that the less perfect our knowledge, the more complete our schemes of classification; the existence of clear classifications is an expression of ignorance. They also lead to the inference that there has been, and is still, a gradual evolution of forms of life. Could we have before us all the forms that exist and have existed (it is important to bear in mind the immense numbers of totally extinct creatures, mostly only represented by often unintelligible fragments), it might be impossible to define a line separating man from the amœba.

Animals and Plants.

More than this, it is not possible to draw a clear line between plants and animals. The only line that can at present be absolutely drawn is between living creatures and minerals. To divide nature into Organisata and Inorganisata is really the only scheme of classification that can be fully proved.

As to animals and plants, it may be useful to point out some of the more salient features by which they are separated. But it will conduce towards clearness if, first of all, their *essential similarities* are enumerated. Plants, like animals, are built up of cells, or else exist as single cells. The cells in both consist essentially of a mass of protoplasm, of similar composition, enclosing a nucleus (or nuclei).

The nucleus, in dividing, may or may not, in both, undergo that elaborate series of changes collectively termed karyokinesis (see p. 129).

All multicellular plants, like multicellular animals, begin life as a single cell, the ovum or oosphere.

This single cell may, or may not (parthenogenesis), in both require fertilization. Fertilization consists, in both plants and animals, of the union of a small motile sex-cell (spermatozoon or antherozoid) with a larger quiescent sex-cell, the ovum or oosphere, the union in both being chiefly a union between the nuclei of the respective sex-cells.

These are some of the more important likenesses between animals and plants, and it is obvious that they are so numerous and so important that plants and animals must have come originally from the same stock.

Next for the *essential differences.* Plants and animals differ in physiological characters as well as in morphological.

1. Plants, as a rule, derive their carbon from the carbonic acid of the atmosphere, by the help of chlorophyll, which is generally prevalent in the vegetable kingdom; the other substances which build up their bodies are absorbed as inorganic salts from the soil, or from the water in the case of aquatic plants.

Animals, on the other hand, require as food organized substances, living or dead protoplasm, animal or vegetable. Even a creature so low in the scale as *Amœba* would starve if kept in water that contained all the components of its protoplasm in the form of salts in solution. It eats solid particles of animal or vegetable matter.

To this rule there are exceptions, both on the animal and on the plant side. In the first place, there are animals with chlorophyll and plants without it. *Hydra viridis*, certain infusorians, etc., have chlorophyll, and can therefore obtain carbon from the atmosphere. In the case of *Hydra* we may, it is true, have to do with a symbiotic organism, but there are infusorians in which the chlorophyll seems to be undoubtedly an integral part of the animal. On the other hand, there are the insectivorous plants and the non-chlorophyllaceous plants. The insectivorous plants form a physiological assemblage of dicotyledonous plants belonging to more than one natural order, which agree in the fact that they possess various mechanisms for the capture, digestion, and absorption of insects and other small creatures. They produce a digestive fluid, which can convert proteids into the diffusible peptones, and they do not thrive so well without as with animal food. The sundew of this country is an example of an insectivorous plant. The fungi are plants which do not contain chlorophyll. Beside fungi, there are more highly organized plants, such as the parasitic dodder, which are also without chlorophyll. These plants prey upon other plants, or upon decaying animal or vegetable substances; the moulds, which cover dying wood, manure heaps, and other masses of organized matter, are examples. These plants feed so far like animals in that they absorb organized compounds which, as an animal, they break down chemically within their protoplasm, and then reconstruct into the protoplasm of their bodies. These fungi, however, do not always live in this animal fashion. Plants without chlorophyll can live in fluids containing the elements of which their protoplasm is built up combined into salts, but the salts must be, some of them, organic compounds. Such a solution as Pasteur's solution is fit for the growth of fungi. Its composition is as follows :—

Water, H_2O.
Cane sugar, $C_{12}H_{22}O_{11}$.
Ammonium tartrate, $(NH_4)2C_4H_4O_6$.
Potassium phosphate, K_3PO_4.
Calcium phosphate, $Ca_3(PO_4)_2$.
Magnesium sulphate, $MgSO_4$.

An animal such as an amœba cannot live in this fluid. As to the exact way in which the food stuffs are taken into the body, the plant differs from the animal. The amœba ingests solid particles; it gets outside its food. This mode of nutrition extends to the highest animals. In the intestine of man, for example, fat particles are eaten up by cells of the intestine, the amœboid independence of the individual cells being thus retained. This has been shown to be the case with many animals. In a hydra many particles of food are devoured by separate cells, and then, after digestion, passed on and used for the common good. Plants do not absorb their food in this fashion. It is taken in as fluid (we are speaking, of course, of the animal-like plants), not devoured separately as solid particles. This difference between animals and plants might, at first sight, be supposed to depend upon a structural difference between the two "sub-kingdoms" to be mentioned presently—the general presence of a rigid cell-wall in the plant and its fairly constant absence in the animal. Given an outer cell-wall, the taking in of nutritious matter must necessarily be limited to the process of osmosis. If two fluids (or gases) of different specific gravity be separated from each other by an animal membrane, it will be found, after a time, that the two fluids have, both of them, passed through the membrane. The amount which has passed from one side to the other depends upon their different specific gravities. This is purely physico-chemical osmosis. In living animals and plants the same phenomenon is met with, but the living protoplasm is supposed to alter the purely physical nature of the diffusion. It has been shown that the presence of the cell-wall is not the only reason for the fact that a true plant does not take in solid particles of food, for in many motile unicellular plants (such as *Hæmatococcus*), where the protoplasm is at times in the plant's life perfectedly naked, no protrusion of pseudopodia and absorption of particles has been noticed.

On the other hand, it must be remembered that the animal body is also fed by similar process of osmosis. The food taken into our stomachs is chiefly thus absorbed. But many of the foodstuffs used by us are non-diffusible substances. This is the case, for example, with albumen, such as white of egg. What happens is that the stomach and other regions of the gut secrete a digestive juice such as gastric juice, succus entericus, etc., which converts these indiffusible substances into diffusible ones. They can then be absorbed by osmosis. This, however, again, is not distinctive of the animal as opposed to the plant. The insectivorous plants have been already referred to. In them a juice is thrown out which actually produces the same effects upon the proteids of a fly's body, and converts its insoluble proteids into soluble peptones, which are then absorbed.

We may conclude, however, by emphasizing the fact that, while plants generally live upon inorganic and organic salts, animals never do; that plants generally absorb their carbon from the atmosphere by the help of their chlorophyll, while animals rarely do; that the nourishment of plants is never taken in as solid particles, while that of animals nearly always is, to some extent.

2. A point of unlikeness between animals and plants that is often emphasized is the power of locomotion possessed by the one group and deficient in the other. Broadly speaking, it is true that animals move from place to place, and that plants do not. With the higher plants it is rigidly true. The cause for this is to be found in the histological structure of plants; each cell being enveloped in a stiff cell-wall is, of itself, sufficient to prevent locomotion. That this is so is proved by the fact that simple naked plants, such as simple algæ, "Flowers of Tan,"[1] etc., do move, and rapidly, from place to place. But, though there is but little locomotion, there is plenty of movement among plants. We need not refer to the bursting of seed-vessels, which are due to purely physical causes, such as the swelling and consequent rupture of certain parts. But genuine movements of protoplasm, often affecting a considerable part of the plant, take place. It is enough to remind the student of the sensitive plant of the folding and unfolding of flowers at night and morning, etc.

These are the principal physiological differences between animals and plants. We shall now discuss their morphological unlikeness.

1. The shapes of animals and plants markedly differ. Apart from the unicellular forms, the animal has usually a symmetrical and very solid body. The plant is, as a rule, not symmetrical; the body is much made of flat expansions. This difference, though morphological, really depends upon the physiological considerations already dealt with. The plant being stationary, and feeding upon gases and fluids, has to have as large a surface as possible for their absorption, and to ramify as much as possible for the purpose of collecting the food gases and fluids.

Animals, on the other hand, are, as a rule, locomotive, and hence their prevailing bilateral symmetry; when they are

[1] This organism is, however, considered an animal by perhaps most naturalists.

stationary, the symmetry, if marked, is rather radial, such as sea anemones, etc. The process of feeding, too, is different: solid food is taken in, which is rendered diffusible by the processes of digestion; it is thus the internal structures which tend to become complicated. There is no need of so much surface. The animal either goes in search of its food by moving from place to place, or—if fixed—it possesses mechanisms, such as the tentacles of hydra, for capturing it. It is interesting to note that certain parasitic animals (some Crustacea), which are imbedded among plenteous nutriment in the bodies of their hosts, often tend to grow in length and irregularly, like plants.

2. Related to the last-mentioned difference between animals and plants is the fact that all the Metazoa—the animals above the unicellular creatures, which will be dealt with later—are either permanently or temporarily two-layered sac-like creatures; the Metaphyta are never so.

3. It is commonly, but in some ways with insufficient accuracy, stated that animals and plants differ in the prevailing cellulose cell-wall of the latter and its absence in the former. The statement is, indeed, perfectly true, but the emphasis is wrongly laid. This difference is, in the first place, that in animals the motile phase is the more prevalent, in plants the encysted. It will be remembered that the amœba is for the most of its life a naked mass of protoplasm; but that on occasions it becomes encysted. On the other hand, the prevailing conditions of organisms on the same plane as amœba, such as the unicellular Alga, *Hæmatococcus*, is usually enveloped in a cell-wall; on occasions this is thrown off, and the creature moves through the water a naked mass of protoplasm. Animals are, however, to be distinguished from plants by the fact that their cell-wall, when present as a distinct structure, is not made of cellulose.[1] In plants it is, as a rule.

It will be gathered from the foregoing brief account of the main differences between animals and plants that there is no

[1] It must be remembered that cellulose is not absent from animals; it occurs, for example, as a constituent of the test of Ascidians. But, when present, it does not form the walls of individual cells.

absolute criterion for determining whether a given unicellular or few-celled organism is a plant or an animal. Hence it follows that there are organisms which have been tossed about from the vegetable to the animal sub-kingdom, and back again. To these doubtful organisms the term "Protista" was applied by Hæckel. An organism known as *Euglena* will serve as an instance. It moves about freely by means of a flagellum, and has an œsophageal tube like a Vorticella, and therefore feeds like an animal; but it has also chlorophyll, and at times becomes encysted, the cell-wall being composed of cellulose. There is not, however, much classificatory advantage to be got by using the term "Protista;" for it only doubles the difficulty. We have, without this division, only to distinguish between animals and plants; with it, between animals and Protista, and between plants and Protista. The facts simply emphasize the common descent of all living beings from a common stock.

CHAPTER XV.

THE CLASSIFICATION OF ANIMALS.

BETWEEN *Amœba* or *Vorticella*, on the one hand, and *Hydra* on the other, is a great gap. The two unicellular organisms are representatives of the **Protozoa**, while *Hydra* and all the other animals dealt with in this book are **Metazoa**. These two fundamental divisions of the animal kingdom are sometimes—and inaccurately—defined as being respectively unicellular and multicellular animals. This definition would, it is true, suffice, if we had only the animals described in the present book to deal with. But there are organisms exceedingly like *Vorticella*, which yet form colonies branching from common stalks; but the individuals forming these colonies are independent of each other, and each feeds itself and propagates its kind on its own account. So that mere multicellularity is not the essential difference between Protozoa and Metazoa. The hydra is not only multicellular, but the cells are specialised in various directions. There are digestive cells, muscular cells, and so forth. Even at this point we have not reached the real difference of metazoon from protozoon; for, in *Volvox*, a colonial protozoon, there are special cells set apart for reproduction, while something of the same kind occurs in the colonial form *Proterospongia*, where there are amœboid and more highly specialised cells imbedded in the same mass of supporting jelly.

The essential difference between the protozoa and the metazoa are two.

1. The Metazoa consist, either temporarily or permanently, of a two-layered sac surrounding a central cavity, which opens on to the exterior at one end, the cells of the inner layer

(endoderm) being different from those of the outer layer (ectoderm).

That *Hydra* is a simple form of metazoon, in which these characters are not much more than just complied with, will be obvious from the preceding description. It is a two-layered sac, only complicated by the outgrowth of the tentacles round the orifice at the anterior end.

That this definition also applies to the remainder of the animals treated of in this volume will be clearer from their development. In all of them the embryo is at one time clearly composed of a two-layered sac, the gastrula, with a central cavity and an aperture at one end of the body. Disguised though this gastrula stage may be, owing to various reasons, but chiefly the mechanical effect of large masses of yolk in the egg, the gastrula stage has been identified in all animals whose development has been studied. They all pass through a two-layered stage, in which they more or less closely resemble *Hydra*. A second essential character of the Metazoa may be stated as follows :—

2. The cells of the metazoon body are grouped into tissues which act as a whole, not each cell for itself, and in subordination to the needs of the individual.

This character is placed second in place and in importance to the first character of the Metazoa, and for the following reasons :—

In the first place all the tissues of the body are not a group or layer of cells which act as a whole and in subordination to the rest of the body. The reproductive tissues are in some respects an exception. The ovum of the hydra, as already said, actually devours the neighbouring cells precisely as if it were a parasitic *Amœba*. If it be objected to this that this is really an act for the common good of the tissues composing the body, for the organism as a whole, as it is essential for the propagation of the species, it may be replied that the protozoa show precisely the same phenomenon, *i.e.* the reproductive cells of *Volvox* and *Proterospongia*. In the same Protozoa and in other multicellular forms it is difficult to suppose that the cells furthest from the surface of the colony are not fed by particles of food captured by and passed on to them by the more superficial cells. To this it may, of course, be answered that, after all, each cell does, as a matter of fact, act independently in taking up food particles; that there is no throwing out of a digestive fluid by the cells at large and a subsequent absorption of the digested food, as in the stomach and intestines of the higher animals. But in *Hydra* the individual cells lining the enteron do take up separately particles of food; and this process of assimilation appears to go on even in the highest animals —witness the absorption of fat drops by the intestinal cells.

Still, on the whole, the second definition of the Metazoa is correct.

To these two definitions is sometimes added a third—that sexual generation is universal. This, however, is only a difference of degree, and the intermediate stages offered by such forms as the colonial Protozoa appear to do away with any marked distinction of this kind. (See the remarks on p. 183.)

We can thus primarily divide the animal world into two great divisions—the Protozoa and the Metazoa.

The vast assemblage of animals which fall into the second division show immense differences among themselves, which permit of a further subdivision. If we compare the lowest representative of the Metazoa with which we are concerned here, the hydra, with any of the higher forms, we find it to be marked off by two features of great importance, which are related to each other. The body of the hydra is built up of two layers of cells only, which surround a central cavity. In all the remaining Metazoa not only are there these two layers present, but also an interpolated layer, which is more or less excavated into a cavity, or set of cavities, lying between the ectoderm and the endoderm; to this cavity or cavities the term *cœlom* is applied, and the animals which possess it are called **Cœlomata**.

The group of Metazoa typified by hydra, and the group typified by any of the other forms, used to be distinguished as Diploblastica, or two-layered animals, and Triploblastica, or three-layered animals. But in many of those creatures, which are better termed Cœlentera, there is a third layer of cells, derived from both ectoderm and endoderm, which is interpolated between them in a jelly-like matrix, the supporting lamella. So that, although the two-layered condition is the characteristic one of the Cœlentera, some of them are truly triploblastic. But in none of them is the interpolated Mesoglæa excavated by a cœlom. The one central cavity is both enteron (gut) and cœlom. In the cœlomata these two cavities are separate.

The Cœlomata contain all the types described in this volume, with the exception of the hydra. And we have described representatives of many of the important divisions. Leaving aside certain small groups whose relationships are a matter of doubt, and would require, therefore, a more elaborate discussion than space can be found for here, the Cœlomata may be grouped round the following types of animals:—

(1) Liver fluke (PLATYHELMINTHES); (2) Thread-worms (NEMATODA); (3) Sea-urchin (ECHINODERMA); (4) Earthworm (ANNULOSA); (5) Lamp-shell (BRACHIOPODA); (6) Sea mosses (BRYOZOA); (7) Snail (MOLLUSCA); (8) Cockroach, Astacus (ARTHROPODA); (9) Frog (CHORDATA).

It may be useful to sketch briefly the characters of all of these groups. The Mollusca, Arthropoda, and Chordata will be dealt with more elaborately.

I. PLATYHELMINTHES.

This large group includes, not only the Trematoda, represented by the liver-fluke, but the Planaria (fresh-water, marine, and terrestrial worms), and the Cestoda (the tape-worms).

By many the Nemertine worms are included in the same great division. These "worms" are more or less flattened, sometimes elongated in shape. They are not definitely segmented, like the Annulosa, though traces of segmentation are occasionally apparent, as in the metameric arrangement of certain of the internal organs in *Gunda segmentata.* The cœlom is feebly developed, and at most consists of chinks and minute cavities in the mesoderm. They have a pair of cerebral ganglia, but no ganglionated ventral cord. In the free-living forms the body is often ciliated. It is only among the Nemertea that a vascular system is present. The nephridia are branched and complicated, and terminate in "flame cells" —*i.e.* a single cell with a single flagellum attached, not a wide and multicellular funnel, as in the Annelids.

II. Nematoda.

The typical members of this group are the parasitic thread-worms, of which the thread-worms of the horse and the *Trichina* are examples. But allied to this group, and possibly to be included within it, are the marine and pelagic Chætognatha. The most striking peculiarity—which, however, they share with the Arthropoda—is the complete absence of cilia in the true Nematoda. The body is unsegmented in the latter, and the alimentary canal lies in a spacious cavity which has not all the characters of a true cœlom. The members of this group have often complicated life histories (as have also various parasitic Platyhelminthes), passing part of their existence as free-living worms and part shut up within the bodies of one or more hosts.

III. Echinoderma.

This group of animals includes the starfishes, sea-urchins, sea-lilies and fossil encrinites, sand-stars, and sea-cucumbers, or holothurians. All the members of the group present a more or less pronounced radial symmetry. In all there is a considerable, often massive, calcareous skeleton, mesodermic, and regularly arranged in plates and spines. The cœlom is spacious, and a part of the cœlom, in the shape of regularly arranged canals, is known as the water vascular system.

IV. Annulosa.

These "worms" are usually segmented animals; but a number of forms belonging to the group, known as the Gephyrea, and doubtfully included here, show but little traces of segmentation. The earthworms, marine worms, and leeches are, however, all of them, plainly segmented, the internal organs being largely arranged in correspondence with the external segmentation. The Annulosa have a well-developed cœlom metamerically divided, and a complete and closed vascular system. The excretory organs are typically a series of pairs of tubes, also metamerically arranged. The nervous system consists of a supra-œsophageal pair of ganglia, and of a ventral cord connected with this by a circum-œsophageal commissure, which is ganglionated excepting in the Gephyrea. There are usually setæ—bristles—imbedded in the skin, which are used for progression.

V. Brachiopoda.

These animals are marine, with the appearance of bivalves. They are, however, more allied to the Annelids in structure. The valves of the shell are dorsal and ventral, not lateral as in the Pelecypoda. The cœlom is spacious, and one or two pairs of quite typical nephridia exist. Setæ are sometimes present.

VI. Bryozoa, or Polyzoa.

These are small and, with one exception, invariably colonial animals, which secrete a thick horny or calcareous skeleton; the numerous "cells" of the colony form incrustations upon plants, stones, etc., or form erect masses of a solid or branched character. The mouth has a circle of tentacles, as in the Brachiopods; there is a spacious cœlom, from which, in a few cases, nephridia have been observed to lead to the exterior; the gut is U-shaped, and between mouth and anus lies a ganglion. They always multiply by buds, as well as by the sexual process.

VII. Mollusca.

The Mollusca are, as their name denotes, soft-bodied animals, which are generally protected by a shell. As a rule, they are entirely unsegmented; but traces of segmentation occur in the divided shell of *Chiton*, and in the double excretory system of *Nautilus*. The cœlom is always greatly reduced, the copious lacunæ between the organs of the body being a portion of the vascular system, which is well developed, with a heart of comparatively complicated structure. As a rule, the ventral surface of the body projects more or less as a muscular "foot," which is the organ of locomotion. Branchiæ are present, and consist of processes of the body-wall. The nervous system consists typically of a pair of cerebral ganglia, lying above the œsophagus, connected by a pair of commissures, with the pedal ganglia lying in the foot, and with a pair of chlamydo-splanchnic ganglia in the visceral region. The Mollusca have been primarily divided into the Lipocephala (Mollusca without a head), the Lamellibranchiata, or Pelecypoda, such as *Anodon;* and the Glossophora, with a head and the characteristic radula: to this group belongs the snail. We shall divide them into four classes—the Amphineura, the Lamellibranchiata, the Cephalophora, and the Cephalopoda—whose characters, and those of their more important sub-divisions, will now be given.

Class 1. *AMPHINEURA.*

To this class belongs the genus *Chiton* and its allies; the Chitons are characterized by the dorsal shell consisting of a number of pieces following each other. The animals of this class are bilaterally symmetrical.

Class 2. *LAMELLIBRANCHIATA*, *or PELECYPODA.*

To this second class belong all the bivalved Mollusca which are without a distinct head and possess no radula. They are bilaterally symmetrical; the generative organs are simple. Examples: with two adductor muscles, *Anodon*, *Mytilus* (the marine edible mussel); with one adductor muscle, *Ostrea* (oyster), *Pecten* (scallop), etc.

Class 3. *CEPHALOPHORA.*

These Molluscs have a head and a distinct radula (only wanting in rare cases such as the Nudibranch *Doriopsis*). The body is symmetrical, and the shell is single. The symmetry of the body is more perfect in some than in other forms. In those in which it has advanced furthest there is but one gill instead of two, and one nephridium. In others there are two nephridia, but one is smaller than the other. The generative organs are generally complicated, but are simpler in the forms which have most nearly retained the primitive bilateral symmetry. The Cephalophora may be divided into the following subclasses: Prosobranchs, Heteropods, Opisthobranchs, Pteropods, Pulmonates, and Scaphopods. We shall briefly consider the characters of these subclasses.

1. **Prosobranchs.**—Of this group, which are characterized by the fact that the gills lie in front of the heart, the simplest forms are those which have been termed the "Zygobranchia;" in them there is so much of the bilateral symmetry retained that the gills are two—save in the limpet (*Patella*), where there is a nearly complete circle of gills—and the nephridia are also double, though one may be larger than the other. Two auricles, moreover (as in Lamellibranchs), exist in *Haliotis*. In these forms there are no special generative ducts; the nephridia serve as such. The more advanced Prosobranchs are termed the "Azygobranchia." They have but one gill, the right; only one nephridium, the left, is retained. The sexes are separate, and there are special generative ducts. To this division belong the fresh-water pond-snail, *Paludina* (Fig. 82), and the bulk of marine univalved "shell fish," such as the whelk (*Buccinum*), cowrie-shell (*Cypræa*), *Conus*, the periwinkle (*Littorina*), the purple-producing *Murex*, etc.

2. **Heteropoda.**—By some associated with the last division,

the Heteropods differ from the forms already considered in the subdivision of the foot into three regions, pro-, meso-, and metapodium. They are pelagic creatures, and the foot has in

FIG. 82.—*Paludina vivipara.*

FIG. 83.—*Limnæa peregra.*

consequence become a swimming organ. The shell is unimportant, and has in some species disappeared.

3. **Opisthobranchia.**—In these the gill (single) lies behind the heart. The shell is often absent altogether, and when present is frequently small and enveloped in the mantle. These Molluscs are hermaphrodite, and have complicated reproductive organs with various accessory glands. The common *Aplysia* represents one section of this group in which the single gill, the

FIG. 84.—*Planorbis lineatus.* Enlarged.

mantle and the shell, though a small one, have been retained. These Opisthobranchs are termed "Palliata." The non-palliate division includes the Nudibranchs, which are devoid of mantle and apparently of gills morphologically corresponding to those of the Palliata. In *Doris*, for example, there is a circlet of gills surrounding the anus, which seem to be independent structures. These Mollusca have reacquired a certain amount of bilateral symmetry. Examples of the Nudibranchs are *Doris*, *Eolis*, with numerous processes on the back, which may be respiratory, and which contain branches of the liver, and are armed externally with thread-cells like those of the Cœlentera.

4. **Pteropoda.**—The Pteropods, allied to the Opisthobranchs, are pelagic creatures of a transparent appearance. The foot is somewhat reduced, but in compensation two lateral processes of the foot—present also in some of the Mollusca already considered—are largely developed, and form the swimming organs; these are known as the epipoda. The Pteropods have complicated reproductive organs, and are hermaphrodite. Though there is a pseudo-symmetry, the nephridium and the auricle are single. Some have, and others have not, a mantle-fold and a shell.

5. **Pulmonata.**—This group of Molluscs comes nearest to the Opisthobranchs, and includes, not only the terrestrial snails and slugs, but also the fresh-water *Planorbis* (Fig. 84), and the pond-snail, *Lymdæa* (Fig. 83). The Pulmonates have no gills, respiration being effected by the very vascular walls of the pulmonary chamber, formed by a fold of the mantle. The shell is usually present, but may become atrophied, as in some slugs. The slug *Testacella*, however, has a small shell. The generative organs are complicated, and the animals are hermaphrodite.

6. **Scaphopoda.**—To this group many give equal rank with the larger divisions of the Glossophora. It is, however, more closely allied to the Cephalophora than to any other of the four main divisions allowed here. The Scaphopoda have a characteristic shell, shaped like a truncated elephant's tusk; it is open at both ends, one being narrower than the other. This shell has a cylindrical form on account of the fact that the mantle which secretes it has fused along the ventral surface of the body, thus forming a complete cylinder. Two nephridia are present, and the generative gland is furnished with a duct which opens into the right of these: the duct is, however, not complicated. There is no heart present.

4. *Class CEPHALOPODA.*

The cuttle-fishes are bilaterally symmetrical animals with a well-marked head and a radula. There is usually a shell present, which may be external and internal. The foot has grown round the head; it is broken up into a large number of lobes, the tentacles. In the mantle-cavity is a muscular projection known as the siphon, and probably the equivalent of the epipodia of other Molluscs. The heart is well developed with two or four auricles; there are one or two pairs of nephridia and of gills. The Cephalopoda are divided into the Tetrabranchiata and the Dibranchiata.

Tetrabranchiata: these are the Nautilus and the extinct Ammonites. They have a large external shell, coiled or straight, two pairs of nephridia, of auricles, and of gills. The siphon is incomplete, its edges not meeting.

The Dibranchiata includes all the squids, *Octopus*, *Argonauta*, *Spirula*, etc. The shell is generally internal, but in the paper Nautilus, *Argonauta*, external. The arms bear suckers which are absent in the Tetrabranchiata. The gills, nephridia, and auricles are but a single pair. The siphon forms a complete funnel. An ink-sac is present.

VIII. Arthropoda.

The Arthropoda are animals in which the body is clearly segmented, and provided with segmented appendages. They are bilaterally symmetrical, with a hard exoskeleton. The nervous system is on the Annelid plan, a brain connected by a circum-œsophageal commissure with a ventral ganglionated chain. The cœlom is so much reduced that in many forms it seems to be altogether absent. There are never cilia, excepting only in *Peripatus*. The Arthropoda are divided into two primary divisions: the Crustacea, breathing by means of gills, and the Tracheata, which breathes by means of tracheæ, or invaginated "lungs."

1. *CRUSTACEA.*

The Crustacea are typically aquatic Arthropods, breathing by means of gills or by the general surface of the body. There are two pairs of antennæ. The Crustacea are divided into two groups as follows :—

1. ENTOMOSTRACA, with usually a varying number of segments.

2. MALACOSTRACA, with only nineteen segments.

The ENTOMOSTRACA are divisible into the four orders which follow :—

(1) **Phyllopoda.**—This order contains the comparatively large *Apus*, and the minute water-fleas (Fig. 85). There is often

FIG. 85.—Water Flea (*Daphnia pulex*). Magnified.

FIG. 86.—A *Cyclops*, viewed from the side. Magnified.

a carapace in front. The number of segments may be large (*Apus*) or small (*Daphnia*). The appendages bear gills.

(2) **Ostracoda.**—These Crustacea are minute, and the body is not clearly segmented. The body is enclosed in a bivalve shell, which has adductor muscles like a Lamellibranch. There are seven pairs of appendages, no gills.

(3) **Copepoda.**—The free-living members of this order have a segmented body without a carapace; the abdomen has no appendages. *Cyclops* (Fig. 86), of our fresh waters, is an abundant form. The parasites known as fish-lice belong to this division.

(4) **Cirrhipedia.**—This order contains not only the barnacles, but a number of parasitic creatures, which have become so degenerate that the general definition used here only partly

applies to them. The carapace of the Cirrhipedes (Figs. 87, 88) is strengthened by a number of separate calcareous plates. The body is not well segmented, and the abdomen is rudimentary.

The MALACOSTRACA are divided into three orders, as follows:—

(1) **Leptostraca.**—This order only includes *Nebalia*, and a few allied forms, which agree with the Entomostraca in having a bivalved shell, closed by special muscles, as in Ostracoda, and

FIG. 87.—A Cirrhipede (*Lepas*). (From Claus-Sedgwick's "Zoology.")

FIG. 88.—A Cirrhipede (*Balanus*). (From the same source as Fig. 87.)

in having a larger number (eight) of abdominal segments than are found in the remaining Malacostraca. The thoracic limbs are much like those of *Apus*, being multilobate, and not on the biramous type of the higher Crustacea. The last segment has two long processes ("furcæ"), another Entomostracan feature.

(2) **Thoracostraca.**—In this division all or most of the thoracic segments are united with the head by a cephalothoracic fold; the eyes are nearly always stalked. It is again divided into the *Cumacea*, small Crustacea, with four or five

thoracic segments; the *Stomatopoda*, also with a number of free thoracic segments, and with movable eye and antennule segments; *Schizopoda*, with biramous thoracic limbs; and *Decapoda*, with all the thoracic segments fused with the head. The thoracic appendages are uniramous in the adults, *e.g.* crayfish, crab, lobsters.

(3) **Arthrostraca.**—In this group the eyes are sessile, and there is no cephalothoracic shield. It is divisible into the *Amphipoda* (Fig. 90), with thoracic gills, of which examples are the shore-hopper and the fresh-water shrimp, and the

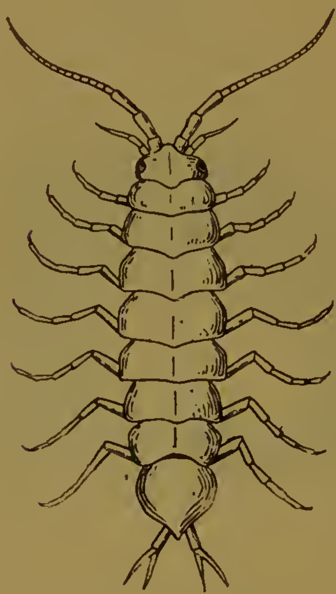

FIG. 89.—*Asellus aquaticus.* Magnified.

FIG. 90.—The Fresh-water Shrimp. Magnified.

Isopoda (Fig. 89), with abdominal gills, of which the best-known example is the terrestrial woodlouse.

2. *TRACHEATA.*

These Arthropods breathe either by tracheæ or lung-books, which may be external or invaginated. There is but one pair of antennæ. They are prevalently terrestrial, while the

Crustacea are mainly aquatic. They may be divided into four classes.

1. **Prototracheata.**—This group includes only the Myriaopod-like *Peripatus*, which, while possessing the characteristic jointed appendages of the Arthropoda, and the tracheæ of the present division of Arthropods, agrees with the worms in having metameric nephridia. It is a caterpillar-like creature found in tropical regions in many parts of the world.

2. **Myriapoda.**—This group includes the centipedes and millipedes. They have tracheæ, like *Peripatus*, but the body is not distinguishable into thorax and abdomen. In the millipedes each segment except the first few is provided with two pairs of appendages; in the centipedes each segment has only one pair.

3. **Insecta.**—Insects have a distinct head, thorax, and abdomen; the latter has no appendages except a few doubtful outgrowths, which may possibly belong to this category (cf. p. 50). The animals breathe by tracheæ. There is an immense variety of insects which are grouped into the orders Aptera (silver fish), a group of very primitive insects, without metamorphosis and without wings; Orthoptera (cockroach, earwig, grasshopper), with biting mouth-parts and but little metamorphosis; Neuroptera (dragon-flies, May-flies), with four membranous wings and mouth-parts of the biting type, and usually a pronounced metamorphosis; Lepidoptera (butterflies, moths), with a complete metamorphosis, four partly or entirely scaly wings, sucking mouth (proboscis); Coleoptera (beetles, with biting mouth-parts, complete metamorphosis, and four wings, of which the first pair, as in the Orthoptera, are horny and not used for flight; Hemiptera (bugs), with incomplete metamorphosis, piercing mouth-parts; Diptera (two-winged flies, *e.g.* house-fly), with only one pair of fully developed wings, piercing mouth-parts and complete metamorphosis; Hymenoptera (bees, wasps, ants), with four membranous wings, biting mouth, complete metamorphosis.

4. **Arachnida.**—This large group comprises Arthropods, which breathe by tracheæ, as in insects, or by lung-books, which may be external, as in the king crab, or internal, as in the

spiders. The head is fused with the thorax to form a cephalothorax. There are four pairs of ambulatory limbs.

Class 1. *Xiphosura.*—This class contains the king crabs (*Limulus*), by some placed with the Crustacea, as a group Gigantostraca. There are really five pairs of ambulatory limbs. The abdominal appendages bear the gills, which are composed of a large number of thin plates, like the leaves of a book. Allied to the king crab are the extinct Trilobites.

FIG. 91.—*Obisium trombidioides.* (From Claus-Sedgwick's "Zoology.") Magnified.

Class 2. *Scorpionida.*—The scorpions have also five pairs of walking limbs; the abdominal appendages of *Limulus* are wanting, but instead there are invaginated lung-books.

Class 3. *Pseudoscopionida.*—These are minute creatures, with large claws like a scorpion, but breathing by means of

FIG. 92.—*Phrynus reniformis.* (From same source.) *Kt*, pedipalpi; *Gb*, flagelliform anterior leg.

tracheæ. The little-book scorpion (Fig. 91), is a common example of this class.

Class 4. *Pedipalpi.*—These are large Arachnids (Fig. 92), in form intermediate between a spider and a scorpion. They have clawed chelicerae, like the last two groups, and breathe by means of lung-sacs.

Class 5. *Solifuga.*—The head in these animals is distinct from the thorax, and the latter from the abdomen. They breathe by tracheæ. The tropical *Galeodes* (Fig. 93) is an example of this class.

FIG. 93.—*Galeodes aranioides.* (From same source.)

Class 6. *Araneina.*—This class is that of the true spiders; they have an entirely unsegmented abdomen. The first pair of appendages, the cheliceræ, are clawed, and bear a poison-gland; they breathe by pulmonary sacs.

Class 7. *Phalangida.*—This class, that of the "Shepherd Spiders," differs from the last in breathing by tracheæ, and that the abdomen is not separated off from the thorax.

Class 8. *Acarina.*—The mites, all of small size, have no separated abdomen; they breathe by tracheæ when breathing organs are present.

Allied probably to the last group of the Arachnids are three little understood groups of Arthropods. The *Linguatulida* are ento-parasites of a vermiform appearance, but of Arthropod characters. Their appendages are represented by hooks. The *Tardigrada* are rather more degraded, though free-living organisms; they have been confounded with the Rotifera. They have short clawed limbs and no respiratory organs. The third group is that of the *Pycnogonida*, sometimes placed among the Crustacea; they are marine and spider-like with a small body and four pairs of sprawling legs. The abdomen is rudimentary.

IX. Chordata.

The group Chordata does not only include the Vertebrata, but also a number of varied organisms, formerly of doubtful affinity, which are now held to be more or less distantly related to the Vertebrata. All of these animals agree with each other to differ from any of the Invertebrate group in the three following particulars:—

1. There are either temporarily or permanently openings from the pharynx to the exterior, the gill-slits.

2. A dorsal rod of skeletal nature exists either temporarily or permanently, and lies above the nervous system; this notochord extends through a greater or less extent of the body, and is hypoblastic in origin.

3. The central nervous system is dorsal in position, and is usually tubular in character. The Chordata, as thus defined, may be divided as follows:—

Class 1. *HEMICHORDATA.*—Sub-class (*a*), **Entero-pneusta**; sub-class (*b*), **Cephalodiscida**; sub-class (*c*), **Rhabdo-pluerida.**

Class 2. *UROCHORDATA.*

Class 3. *CEPHALOCHORDATA.*

Class 4. *VERTEBRATA.*

Some of the main characters of these four classes will now be given.

Class 1. *HEMICHORDATA.*

Sub-class (*a*). **Enteropneusta.**—This sub-class contains only the genus *Balanoglossus*, a worm-like organism. There is a large proboscis, and the gill-slits extend a long way down the body. The notochord, which is an at first hollow, but afterwards solid, outgrowth of the intestine, only exists in the region of the collar and proboscis. The dorsal nerve-cord is imbedded in the skin, and a ventral cord also imbedded in the skin. The cœlom is spacious, but there is nothing that can be definitely compared to nephridia. There productive organs are sacs imbedded in the body-wall, and opening on to the exterior.

Sub-class (*b*). **Cephalodiscida.**—To this sub-class is now assigned an organism (*Cephalodiscus*), showing many resemblances to the Polyzoa, with which it was at first confounded.

Sub-class (*c*). **Rhabdopleurida.** — *Rhabdopleura* is an organism which has also been referred to the Polyzoa. But since, like *Cephalodiscus*, it has gill-slits and a small notochord, it conforms to two out of three essential characteristics of the Chordata.

Class 2. *UROCHORDATA.*

These animals, more generally known as Ascidians or Tunicata, are abundant in genera and species. It is only in the larval stages, and in the persistently larval *Appendicularia* and its immediate allies, that the nervous system is in the form of a dorsal tract, and that the notochord is present. This latter is developed only in the tail, thus contrasting with the Hemichordata, where it is only found in the head region.

Class 3. *CEPHALOCHORDATA.*

To this group belongs only the Amphioxus, of which there are several species. It is an elongated fish-like animal. It has a dorsal nervous system, swelling out in front to something resembling a brain. This nerve-tube is hollow. There are numerous vertically elongated gill-slits, but the young Amphioxus has much fewer, and is more like the Vertebrata in this respect. Excretory organs are present as a series of paired tubes opening into the cœlom on the one hand, and into the atrium on the other—the atrium being a late ingrowth from the exterior which burrows its way among the organs of the body.

Class 4. *VERTEBRATA.*

The word "Vertebrata" is etymologically incorrect when applied to the present group, for the lowest members of it, the lampreys, have no vertebræ. The term "Craniata" often used, is a much more appropriate term. The Vertebrata, or Craniata, are to be distinguished from all the other Chordata by the fact that they possess a definite skull, which is either cartilaginous or bony, or partly cartilaginous and partly bony. The brain is well marked off from the spinal cord. The liver is always a more or less complicated gland, not a mere sacular diverticulum as in Amphioxus. The Vertebrata are divisible into the six following sub-classes :—

Sub-class I. **Cyclostomata.**—The lampreys and hagfishes are so different from the true fishes that they form a definite group apart from them. They have a persistent notochord (round which, however, vertebræ seem to have existed in the extinct Palæozoic *Palæospondylus*) and a smooth scaleless skin (unless the Devonian fishes, *Pteraspis*, etc., are ultimately proved to be Cyclostomes); the skull resembles in many particulars that of the embryos of higher forms; there are no true branchial arches, but a basket-work of cartilages, which strengthen the gills. The Cyclostomes have no limbs, unless certain rudiments in the neighbourhood of the cloaca turn out to be degenerate limbs of the hind pair. The alimentary canal is straight, and the pancreas is absent. There are no teeth, only horny plates, and the mouth is a sucking, not a biting mouth.

Sub-class 2. **Pisces.**—The fishes, as is the case with all the remaining Vertebrates, have two pairs of limbs. These limbs are, however, what is called an Ichthyopterygium; they are not formed on the plan of the five-fingered hand, or foot, of the higher Vetebrates, but are made up of a larger or smaller number of cartilaginous, or bony rays, which cannot be securely reduced to the type of the cheiropterygium.

This is really the only distinguishing feature which absolutely separates all fishes from all Amphibians. The bulk of fishes, however, are so characterized by the fact that they breathe by gills only, and, if there are simple lungs, by gills also: by the fish-like form, with its unpaired fins, and the great development of the lateral line. The Pisces are divisible into the four following groups:—

1. *Elasmobranchii.*—The sharks and skates. The skin is smooth, with scattered spines forming, in some cases, a close investment (shagreen). The skeleton is cartilaginous, the notochord largely persistent. The swim-bladder is entirely wanting; the intestine, furnished with an extensive spiral valve, opens into a cloaca.

2. *Holocephali.*—This limited group of fishes contains the chimæra of northern seas and some other forms. The skeleton is cartilaginous, as in sharks; but the mandible articulates directly with the mass of cartilage forming the skull, there being no free palatoquadrate or hyoid suspensorium. There is a dermal flap (operculum) covering the gill-slits, which are thus not exposed as in sharks. The spiral valve is less conspicuous, and the anus is separate from the urogenital pore. There is no swim-bladder.

3. *Teleostomi.*—This group includes the Ganoids and Teleosteans. Examples of the former are the sturgeon, *Polypterus* of the Nile, etc; of the latter, the vast majority of the familiar fishes, pike, perch, sole, herring, etc. The skeleton is sometimes largely, but never entirely, cartilaginous; in the Teleosts it is nearly always greatly ossified. The body is generally invested with bony plates or scales. The intestine may, or may not, have a spiral valve, and be furnished, or not furnished, with pyloric cæca. There is no cloaca; the gill-slits

are covered by an operculum. A swim-bladder is always present, and is unpaired, except in *Polypterus*, where it is even lung-like in texture, as is the unpaired swim-bladder of *Lepidosteus* and *Amia* (two American Ganoids).

4. *Dipnoi.*—The Dipnoi, or lung-fishes, form a limited group (at the present day) with but three species, the *Ceratodus* of Queensland, the *Protopterus* of Africa, and *Lepidosiren* of America. They are more akin to Amphibia than are any other fishes. The body is scaly, and the skeleton is largely cartilaginous. The viscera are somewhat shark-like. The intestine has a spiral valve, and there is a cloaca. The swim-bladder is single in *Ceratodus*, double in the others; it functions as a lung, and the gills are somewhat reduced. They have the posterior nares (as in *no* fish, but in Amphibians and all higher Vertebrates); the heart is three-chambered.

Sub-class 3. **Amphibia.**—By some the Amphibia are united with the fishes to form a group, Ichthyopsida. The only positive differences that distinguish them have been already mentioned. They contrast with the higher Vertebrate by the fact that the larva always has gills,[1] which may be persistent throughout life, but in that case in conjunction with lungs. The skull is more or less ossified with two occipital condyles for articulation with the vertebral column. There is no spiral valve, but the intestine opens into a cloaca; the heart is three-chambered. As in Pisces, there are ten pairs of cranial nerves. The Amphibia are divisible into (1) the extinct Stegocephali, including the Labyrinthodonts, which were tailed, and had an extensive dermal armature of plates; (2) the Cæcilia, snake-like Amphibians, of underground habit, with scales; (3) Urodela, tailed Amphibians, with usually persisting gills, *e.g.* newt, salamander, axolotl; (4) Anura, tailless Amphibians, without gills, partly terrestrial in habit—the frogs and toads.

Sub-class 4. **Reptilia.**—The Reptiles agree with the Amphibia and with all the higher Vertebrates in possessing the cheiropterygium, which, however, has partly reverted to

[1] With a few exceptions. Thus the tree-frogs leave the egg complete frogs.

a fish-like condition in the extinct *Ichthyosaurus*, etc. They never, however, possess gills. The epidermis possesses a skeleton in the form of scales. The skull articulates with the vertebral column generally by one condyle only; it is almost completely ossified. The gut terminates in a cloaca; the heart is at least three-chambered, and the ventricle may be incompletely or completely divided into two chambers. There are, as in Aves and Mammalia, twelve pairs of cranial nerves. The embryo, like that of the higher Vertebrata, has an amnion. The Reptiles are divisible into nine orders, of which five, viz. the Ichthyosauria, Plesiosauria, Theromorpha, Dinosauria, and Pterosauria, are totally extinct. The orders with living representatives are the Testudinata, Lepidosauria, Rhynchocephalia, and Crocodilia. We will briefly give the characters of the extinct orders first.

1. *Ichthyosauria.*—These are the well-known "fish-lizards" of the middle period of the earth's history. Large, often very large, creatures, with fish-like paddles, and a tail formed by an expansion of the integument, like the tail of a whale.

2. *Plesiosauria.*—The long-necked *Plesiosaurus* is familiar to everybody. It had paddles, in which the individual bones are less numerous than in the *Ichthyosaurus*. They are also mesozoic in time range.

3. *Theromorpha.*—These reptiles are interesting on account of the many points of resemblance which they show to the Mammalia. Their teeth, for example, often show much specialization—canines, molars, etc., being distinguishable; whereas in reptiles generally the teeth are numerous and all similar.

4. *Dinosauria.*—The last group of extinct reptiles present certain likenesses to the Mammalia. The present group is, in many respects, nearly akin to the group of birds. The dinosaurs are mesozoic and were of varied size; some were as small as a crow, others reached a length of sixty feet or so. Their likeness to birds is mainly in the pelvis, but it seems probable, from certain osteological details, that the bones were permeated with air-spaces.

5. *Pterosauria.*—In some ways the pterodactyls also resemble birds. They were flying reptiles with extensive wings,

supported, however, by the elongated digits. Some were toothless, and appear to have possessed beaks.

6. *Testudinata.*—The tortoises and turtles have the well-known and characteristic "shell," which is formed by bony plates, partly formed by the flattened neural spines and ribs and other bones. Covering this is a horny set of plates, which are epidermic in structure. This character absolutely distinguishes the Testudinata.

7. *Lepidosauria.*—This group includes both the lizards and snakes, which are by some made the representatives of two equivalent orders. They agree in the covering of epidermic scales. The teeth are fused to the jaws, and not implanted in distinct sockets. The cloaca opens transversely, and there is a double penis. In both the limbs may be more or less unrepresented; and these are the only reptiles in which the teeth are sometimes grooved or perforated for the poison-glands (=modified salivary glands). The Gila monster (*Heloderma*) and an Oriental form are poisonous lizards; while there are, of course, numerous poisonous snakes. The snakes are separable from the lizards by the incompletely united rami of the lower jaw, which thus permits the swallowing of larger prey; they have no urinary bladder, while the lizards have one. Snakes are more constantly apodous.

8. *Rhynchocephalia.*—This group is represented at the present day by only a single lizard-like animal, the *Hatteria*, or *Sphenodon*, of New Zealand islands. The skull differs in several points from that of the lizard's, and the body is provided in addition to the true ribs with abdominal ribs, also found in the Crocodilia. Some of the ribs bear uncinate processes, as in birds.

9. *Crocodilia.*—These are the most highly organized of living reptiles. The heart is completely four-chambered. The skin has not only epidermic scales, but bony mesodermic plates beneath them in many parts of the body. The teeth are in distinct sockets. The ribs may possess uncinate processes, and, as already said, there are abdominal ribs. The cloaca has a longitudinal opening, and the penis is single.

Sub-class 5. **Aves.**—By many the birds are placed in one great division with the reptiles, which is then called Sauropsida. They agree with them in the single condyle of the skull, and in the fact that the ankle-joint is in the middle of the tarsus, and not between the tarsus and the tibia and fibula, as in other Vertebrates. Birds, however, differ from reptiles in the peculiar modification of the fore-limb to form the wing (see above), in the presence of feathers, which is itself sufficient to define birds. The blood is hot; the heart is four-chambered. The bones and viscera are permeated with air from the air-sacs, which are prolongations of the lungs, and are developed to an extent never found in reptiles, with the possible exception of the extinct Dinosaurs (cf. p. 205).

Sub-class 6. **Mammalia.**—The Mammals are separated from all other Vertebrates by a number of important points. They differ from all in the presence of mammary glands, with which the young are suckled, and by the hairy covering which is rarely nearly or quite absent, as in the whales. In all Mammals a complete muscular septum, the diaphragm, separates a cavity containing the heart and lungs from the cavity in which the intestine, liver, and the rest of the viscera, lie. These three characters—or, indeed, any one of them alone—is amply sufficient to define a Mammal.

The Mammalia are commonly divided in the first place into three different divisions: the *Prototheria*, *Metatheria*, and *Eutheria*.

To the *Prototheria* belong only the *Platypus* and the *Echidna*, both Australian, and distinguished by the fact that they lay large-yolked eggs, that they possess a well-developed coracoid, and a cloaca. The mammary glands open on to the skin, and are enclosed by a pouch, which really represents the teats, not drawn in into a teat-like form.

The *Metatheria* are the marsupials, the kangaroos, wallabies, native bear, etc., which have, for the greater part, a well-developed pouch, into which the separate teats open, and in which the young are carried. The young of the marsupials are born in a very imperfect condition. The egg, however, is minute, like that of the Eutheria. There is just a vestige of the cloaca remaining.

The *Eutheria* are the rest of the Mammalia. They have no cloaca, or at most, a trace of one. The egg is minute without yolk. A pouch is absent. The coracoids (as also in the marsupials) are minute processes of the scapulæ.

Of Eutheria there are a large number of existing orders.

The Edentata (sloths, armadillos, aard vark, pangolin).

Sirenia (manatee, dugong).

Ungulata (horses, oxen, deer, antelopes, rhinoceros, tapir, elephant).

Cetacea (whales, dolphins, porpoise, narwhal).

Rodentia (rabbit, rat, porcupine, guinea-pig).

Carnivora (cat, dog, bear).

Insectivora (mole, shrew).

Chiroptera (bats).

Primates (lemurs, monkeys, gorilla, chimpanzee, man).

There are besides a number of extinct orders.

EXAMINATION PAPERS.

First Stage, or Elementary Examination.

You are permitted to ATTEMPT *only* EIGHT *questions.*
Illustrate your answers by diagrammatic figures.

1895.

1. Describe a tentacle of Hydra as seen by the microscope. Point out the uses of the tentacles, and of any of their component parts. (11.)

2. Compare the general structure of a Hydra with that of an Anemone. (11.)

3. In what ways does an Echinus move about and masticate its food? Describe the organs employed for these purposes. (13.)

4. Describe the structural peculiarities of the alimentary canal (including the mouth) of a Leech, and show how they are connected with the mode of feeding. (13.)

5. Mention some animal in which the chief organs of the body show conspicuous segmental repetition, and specify the organs so repeated. (11.)

6. Compare the life-history of a Butterfly with that of a Cockroach, and endeavour to account for the most striking differences between them. (13.)

7. Give the general characters of Mollusca. Mention their leading divisions, and give one or two examples of each. (11.)

8. Describe the pharynx of Amphioxus, and show how it is adapted to assist in nutrition and respiration. (11.)

9. Shortly describe the heart of the Dog-fish, and compare it with those of a Frog and a Mammal. (13.)

10. What are the chief peculiarities of the skin of the Frog? Show how some of them promote the safety of the animal. (13.)

11. A bird runs or stands on its hind limbs, and employs its fore limbs in flight. Show that the pelvis, shoulder-girdle, vertebral column, and sternum become modified in consequence. (13.)

12. Point out the features of the Rabbit's skull which are peculiar to Mammalia. (11.)

1896.

1. Mention some Protozoa which have a mouth, and others which have none. How is food taken into the body in each case? (11.)

2. Describe the nerve-cord of an Earthworm. How does it resemble and differ from that of a Crayfish? (11.)

3. How does a Leech move about and take in food? Describe the organs employed for these purposes. (11.)

4. What are the changes which a Butterfly undergoes during the chrysalis stage? (14.)

5. Describe the form and mode of life of a fresh hatched Anodonta Try to account for the large number of eggs produced by a single female. (14.)

6. Give a short account of the respiratory organs of different Mollusca. (11.)

7. Point out the chief differences between the heart of a Dogfish and that of a Frog. (11.)

8. Explain the changes by which a Tadpole with four legs is converted into a Frog. (11.)

9. Describe the process of filling the lungs with air, as observed in the Frog and the Rabbit. (11.)

10. Point out the chief peculiarities of the neck-bones (cervical vertebræ) of a Bird, and show how these peculiarities are turned to account in locomotion or feeding. (14.)

11. What structures form the walls of a Rabbit's thorax? Mention the principal organs contained within the thorax, and show their relative position as seen in a cross-section. (11.)

12. Describe structures in the Rabbit, Frog, Dogfish, and Earthworm, which increase the internal surface of the intestine without increase of its length or diameter. (14.)

1897.

1. Describe the hind foot and tongue of the Frog, as seen by the naked eye. Point out the advantage of any peculiarities which they exhibit. (10.)

2. How does the fact that a Bird stands upon two legs affect the skeleton of the trunk? (14.)

3. Describe some of the external defences which are formed out of the epidermis of Vertebrates. (14.)

4. Give a short account of the yolk of a Fowl's egg. Where is it formed? What is its use? What becomes of it during hatching? (14.)

5. Refer the following animals to their classes, giving reasons in each case: Perch, Cockle, Goose, Seal, Mouse, Viper, Tadpole, Crab. (10.)

6. Describe the position and structure of the nervous system of the Crayfish. (10.)

7. Describe the external appearance of the pupa of the Blow-fly. What internal changes go on during this stage? (14.)

8. Where is the mouth of the Pond-mussel situated? What is its shape? How is food brought to it? (10.)

9. Where is the lung of a Snail situated? How do we know that it is really a lung? (14.)

10. Describe the alimentary canal of the Earthworm, and point out the uses of any peculiar features. (10.)

11. How does Vorticella feed? What becomes of the food after it is taken into the body? (10.)

12. Give a short description of Amœba. How does it feed and increase in numbers? (10.)

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